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Graph and table use in Special Education: a review and analysis of the communication of data

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An emerging line of research demonstrates a distinction between social and natural sciences; natural sciences devote more page space in journals to data graphics than social sciences. The present survey asked how the subdiscipline of Education, Special Education, compares to other disciplines of science. Also, how do the Individuals with Disabilities Education Act (IDEA) disability category subfields use data graphics and tables? And last, has the use of data graphs and tables changed over time within Special Education? After reviewing 29 representative journals and over 8500 graphics and tables, the results show that Special Education ranks near the bottom of the natural and social sciences. As a field, the IDEA disability category subfields use tabular displays of data more often than data graphics. The results also demonstrate that over a 15-year time span the use of data graphics and tables used in journals to communicate data has remained stable.

Keywords: fractional graph area; fractional table area; Special Education journals; scientific communication

Many societal improvements have resulted from the use of data graphs. For example, Robert Plot's graph called a 'History of the Weather' displayed the barometric pressure in Oxford for all of the days in 1684. Plot's graph, along with colleagues such as Martin Lister and William Molyneux, would lead to the development of modern weather graphs some 300 years later (Wainer, 2005). Another striking example of the utilitarian power of data graphics occurred in 1854 when cholera struck London. Dr John Snow plotted the location of deaths in relation to 11 water pumps on a map. The results showed those who lived closest to the Broad Street pump had the highest concentration of deaths, thereby revealing the likely cause of the epidemic (Tufte, 1983).

Scientists also use graphs to communicate data. Specifically, data graphics convert complex data into visual representations. The resulting images produce patterns allowing the graph reader to analyse and interpret the data in a fundamentally different manner than by examining numbers alone. In his seminal book, Schmid (1954, p. 3) enthusiastically described the power inherent in data graphics: 'Charts and graphs represent an extremely useful and flexible medium for

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explaining, interpreting, and analyzing numerical facts largely by means of points, lines, areas and other geometric forms and symbols'. Schmid also stated that, 'They make possible the presentation of quantitative data in a simple, clear, and effective manner and facilitate comparison of values, trends, and relationships' (p. 3).

A wide array of data graphics exists for communicating evidence in science. Data maps, graphs, charts, tables and diagrams depict what many now call inscriptions or inscription devices (Latour & Woolgar, 1986). Inscriptions have become central to science, so much so that in the sociology of science Latour (1990) proposed a theory of graphism explaining their role in knowledge construction. In his thesis, Latour distinguished graphs from other inscription devices. Graphs have a number of features that make them influential (Latour, 1990; Smith, Best, Stubbs, Archibald, & Roberson-Nay, 2002):

(1) Readable-graphs transform complex sets of information in a succinct manner.
(2) Scalable-graphs can scale all orders of magnitude from elementary particles such as quarks to astronomical phenomena like planetary orbits.
(3) Combinable-scientists can aggregate and overlay graphs uncovering latent order.
(4) Immutable-graphs capture transient phenomena and transfigure them into enduring visual accounts.
(5) Mobile-scientists can take their graphs from one setting to another (e.g. other laboratories, research sites and conferences).
(6) Persuasive-graphs provide visual representations, which compel other scientists to accept or refute the evidence.

One source of evidence for the vital importance graphs hold in science comes from a survey of graphs in scientific publications. Cleveland (1984a) selected 57 journals from 14 scientific disciplines from 1980 to 1981. He sampled 50 articles from each journal and examined the fractional graph area (FGA). FGA represents the proportion of page space used to display data graphics. For example, an FGA of 0.10 means that graphs would cover an area equal to 10 out of every 100 journal pages. The FGA metric does not translate literally (i.e. 10 pages out of 100 have data graphics), but depicts the proportion or ratio of space devoted to data graphics. Cleveland (1984a) found that the natural sciences (e.g. Physics, Chemistry and Biology) allocated a much greater amount of page space to data graphics, FGA range = 0.06–0.18, than the mathematical sciences (e.g. Statistics, Computer Science and Mathematics), FGA range = 0.019–0.06, and the social sciences (e.g. Sociology, Economics and Psychology), FGA range = 0.014–0.057.

Building upon Cleveland's work, Best, Smith, and Stubbs (2001) examined Psychology and 10 subdisciplines. They found a positive correlation of 0.93 between the FGA of journals and psychologists' perception of which ones represented hard science. The hardest ratings went to *Behavioral Neuroscience* and *Journal of Experimental Psychology: Animal Behavior Processes*, which had FGAs of 0.12 and 0.10, respectively, whereas the journals rated as softest, *Journal of Counseling Psychology* and the *Journal of Educational Psychology*, had an FGA of 0.01. Additionally, Kubina, Kostewicz, and Datchuk (2008) demonstrated that the discipline of behaviour analysis, when broken down into subdisciplines, matched social and natural sciences with FGAs in the same range as their parent disciplines. For instance, behavioural education journals, like the discipline of Education, had lower FGAs than behavioural journals that experimented with animals similar to the discipline of Biology.

A summary of the research pertaining to FGA (Best et al., 2001; Cleveland, 1984a; Kubina et al., 2008; Smith et al., 2002; Smith, Best, Stubbs, Johnston, & Archibald, 2000) shows that data graphics play a considerable role in the natural sciences but have a lesser part in the social sciences. Additionally, the hardness of disciplines directly relates to graph use (Arsenault, Smith, & Beauchamp, 2006). Data graphics use even sets apart science from non-science; the use of data graphics functions as the distinguishing characteristic of the scientific enterprise (Latour, 1990).

Both the scientific discipline of Education and its subdiscipline, Special Education, have set forth guidelines and documents suggesting how science can guide both research and practice. For example, the National Research Council asks ‘What constitutes scientific research?’ and goes on to answer the question by suggesting that certain principles guide science including:

> Seeking conceptual (theoretical) understanding, posing empirically testable and refutable hypotheses, designing studies that test and can rule out competing counter-hypotheses, using observational methods linked to theory that enable other scientists to verify their accuracy, and recognizing the importance of both independent replication and generalization. (Shavelson & Towne, 2002, p. 51)

In like manner, a recent article titled, ‘Research in Special Education: Scientific Methods and Evidence-Based Practices’ discusses quality indicators of research methodology and guidelines for identifying evidence of effective practices or evidence-based practice (Odom et al., 2005).

In both the National Research Council report on scientific research in Education and the prominent *Exceptional Children* article (Odom et al., 2005; *Exceptional Children* is the flagship Special Education journal) describing research in Special Education, neither focused attention on the use of data graphics in the scientific process. The lack of discussion surrounding data graphics may stem from the idea that many scientists feel the standards and traditions for applying guiding principles of science exist within each discipline (Diamond, 1999). If an essential feature of the culture of science involves the use of data graphics, however, disciplines intent on invoking the rich traditions of science would benefit from a critical examination of the use of data graphics.

Therefore, with the emphasis in Special Education on enhancing the scientificity of its discipline, we choose to investigate how the field uses data graphics. Specifically, we engaged in a comprehensive survey of Special Education journals and asked three main questions. First, how does the subdiscipline of Education, Special Education, compare to other disciplines of science in regard to FGA? Second, in the subdiscipline of Special Education, how do the Individuals with Disabilities Education Act (IDEA) disability category subfields use graphs and tables? And third, has the use of graphs and tables changed over time within Special Education?

Methods

Journal selection

To represent categories of disability specified in IDEA, the experimenters compiled prominent Special Education journals targeting specific disability categories. The first step in journal identification involved consulting the Council for Exceptional Children's (CEC) website (CEC, 2005). The website lists CEC division publications. Searching the CEC website resulted in nine peer-reviewed journals representative of an IDEA disability category.

The second step consisted of examining journals recommended by CEC (CEC, 2005) and Special Education journals with a top 25 ranking in Special Education by impact factor listed in the 2004 *Journal Citation Reports* (Thomson ISI, 2004). From the 127 recommended CEC journals and the JCR top 25 impact factor list, 19 met criteria. To meet criteria, a journal had to fulfil the following conditions: (1) appear on the 2004 *Journal Citation Reports* (Thomson ISI, 2004); (2) contain keywords in the mission statement, found within the journal or online, describing a focus on a specific disability; and (3) have a historical record concentrating on a specific disability. To obtain a representative sample of the prominent journals, the experimenters sorted the journals into specific disability categories. Excluding the original nine CEC division journals and CEC's flagship journal *Exceptional Children*, if a disability category contained two or fewer journals, those journals became representative of the category; if a category contained three or more, we included the top two journals ranked by impact factor.

After sorting all of the journals that met criteria, the disability category traumatic brain injury (TBI) did not have an entry. Therefore, a third step called for the placement of additional journals. After examining the *Journal Citation Reports* (Thomson ISI, 2004) category for rehabilitation, only one journal specifically targeted TBI, the *Journal of Head Trauma Rehabilitation*. The three steps for journal selection resulted in 29 journals, displayed in Table 1.

Data graphics and tabular displays of data

The present study examined the display of quantitative information, data, in representative Special Education journals in two formats, data graphics and tables. Tufte (1983, p. 9) provides the following definition of data graphics, 'Data graphics visually display measured quantities by means of the combined use of points, lines, a coordinate system, numbers, symbols, words, shading, and color'. Non-examples of data graphics included flow charts, pictures, conceptual diagrams and mathematical equations.

Data graphics fall into four types: data maps, time series, narrative graphics of space and time and relational graphics. Data maps depict quantitative data with regards to area and location (Harris, 1999; Tufte, 1983). Time series graphics have horizontal axes where time progresses from left to right while the vertical axes maintain a quantitative scale (Harris, 1999; Tufte, 1983). When times series display data with the addition of spatial information, namely when data move over space in two or three dimensions and over time, Tufte calls these narrative graphics of space and time. Relational graphics display one variable quantity in relationship to another variable quantity (Tufte, 1983).

The other format through which journals display data occurs in tables. 'Tables usually show exact numerical values, and the data are arranged in an orderly display of columns and rows, which aids comparison' (American Psychological Association, 2001, p. 147). Included tables contained nominal, ordinal, interval and/or ratio statistical data in 75% of the columns. Data meeting the criteria of the nominal level of measurement must have clearly fit into a defined category (Levin & Fox, 2000).

Table 1. Special Education journals meeting criteria.

Category	Journal	CEC division published	CEC recommended	JCR only	JCR verified
Autism	*Autism: The International Journal of Research and Practice*		X		X
	Journal of Autism and Developmental Disorders		X		X
Early intervention	*Journal of Early Intervention*	X			X
	Infants and Young Children		X		X
Emotional disturbance	*Behavioral Disorders*	X			X
	Journal of Emotional and Behavioral Disorders		X		X
Gifted	*Journal for the Education of the Gifted*	X			X
	Gifted Child Quarterly		X		X
	High Ability Studies		X		X
Hearing impairments and deafness	*American Annals of the Deaf*		X		X
	Volta Review		X		X
Learning disabilities (specific)	*Learning Disabilities Research and Practice*	X			
	Annals of Dyslexia		X		X
	Journal of Intellectual Disability Research			X	X
Mental retardation	*Education and Training in Developmental Disabilities* (Formally known as *Education and Training in Mental Retardation and Developmental Disabilities*)	X			X
	American Journal on Intellectual and Developmental Disabilities (Formally known as *American Journal on Mental Retardation*)		X		X
	Mental Retardation		X		X
Orthopaedic impairments	*Physical Disabilities: Education and Related Services*	X			
	American Journal of Occupational Therapy		X		X
Speech or language impairments	*Communication Disorders Quarterly*	X			
	Journal of Communication Disorders		X		X
	Journal of Fluency Disorders			X	X
Traumatic brain injury	*Journal of Head Trauma Rehabilitation*			X	X
Visual impairments and blindness	*Division on Visual Impairments Quarterly*	X			
	Journal of Visual Impairments and Blindness		X		X
Multi-category	*Journal of Special Education*	X			X
	Exceptional Children		X		X

Table 1. (*Continued*).

Category	Journal	CEC division published	CEC recommended	JCR only	JCR verified
	Research & Practice for Persons with Severe Disabilities		X		X
	Topics in Early Childhood Special Education		X		X
Totals	29	9	17	3	26

Nominal data that lacked classification labels, such as qualitative descriptors, did not count as a statistical data column.

Fractional graph area (FGA) and fractional table area (FTA)

Following the identification of a data graphic, the experimenters measured the amount of page space devoted to that graphic display of data, Cleveland's (1984a) FGA. Measurement of FGA consisted of the following: finding page area (PA) by measuring length and width of each page in centimetres (cm) and multiplying the two measures; and finding graph area (GA) by measuring the length and width of each graph in centimetres (cm) and multiplying the two measures. After obtaining PA and GA, calculation of FGA consisted of dividing GA by PA (i.e. GA/PA = FGA). The resulting quotient represented FGA for one graph.

After identifying an included table, the experimenters measured the amount of page space devoted to that table, Best et al. (2001) fractional table area (FTA). Measurement of FTA followed a similar process to FGA: finding PA by measuring length and width of each page in cm and multiplying the two measures; and finding table area (TA) by measuring the length and width of each table in cm and multiplying the two measures. After obtaining PA and TA, calculation of FTA consisted of dividing TA by PA (i.e. TA/PA = FTA). The resulting quotient represented FTA for one table.

Procedure

To attain a stable, representative sample of the selected journals, the experimenters measured four volumes over a 15-year span. Volume years encompassed 2004, 1999, 1994 and 1989. Two journals began publication post-1989 (i.e. *Journal of Emotional and Behavioral Disorders* and *Learning Disabilities Research and Practice*) and another two began post-1994 (i.e. *Autism: The International Journal of Research and Practice* and *High Ability Studies*). Within each volume, all issues qualified for the survey. The specific number of issues ranged from 2 to 6 issues per volume. An issue published outside of the specified volume year, but still inclusive of a volume (e.g. issue #1, Fall, 1998 or issue #6, Spring, 2000), counted in the sample.

Examination of specific issues involved an analysis of research articles. Non-research articles entailed: book reviews; obituaries; letters to the editor; editorial commentary; interviews; meeting notes; and specifically titled features, such as commentaries, pharmaceutical reviews, product reviews, and news updates. Regardless of classification, the experimenters included all non-research articles containing targeted graphs or tables. All research articles and non-research articles including graphs and tables formed the total number of pages for an issue.

After determining the total pages for an issue, the experimenters measured identified graphs and tables with a six-step procedure. First, we measured PA as described previously. We multiplied one PA by total number of the aforementioned identified page total resulting in total PA for an issue. Second, we assessed GA or TA for one page by measuring the width and height of each graph and/or table. Width took in the farthest left to right points while height covered the lower to upper most points of the graphic or table. The outermost points included table titles, notes, captions, labels and page break lines. Third, we calculated the FGA and/or FTA per page by dividing the GA or TA by total PA. Fourth, to calculate FGA and FTA for one issue, we summed each page's FGA and FTA. Fifth, we repeated the previous four steps, averaging all issues' FGAs and FTAs, resulting in a volume FGA and FTA. And sixth, we found the average volume FGA and FTA for each journal title.

Reliability

To measure reliability, we randomly selected 20% of the issues. A trained independent observer measured FGA and FTA for the selected issues. Using a total agreement approach (Kennedy, 2005), the smaller measurement divided by the larger measurement multiplied by 100% resulted in a per issue agreement. An average of all of the issues' agreement yielded 98% agreement for FGA and 97% agreement for FTA.

Results

The sample of 29 Special Education journals included a total of 3290 articles encompassing 38,015 pages meeting criteria. The total pages contained 2203 graphs and 6337 tables. Mean article length came to 11.6 pages with an average of 0.67 graphs and 1.93 tables per article. Total PA covered 16,165,726.19 cm^2, approximately 1617 m^2 or 0.4 acres. Of the total PA, graphs comprised 296,206. 56 cm^2 or 29.62 m^2, while tables constituted 693,912.77 cm^2 or 69.39 m^2.

Comparison of Special Education to other disciplines of science

The sample of journals representing Special Education permitted a comparison to other disciplines of science. Based on Cleveland's (1984a, Figure 3, p. 264) survey, we used his data to represent the FGA of 13 disciplines of science. Figure 1 shows a dot chart (cf. Cleveland, 1984b, for dot charts) displaying Special Education and the 13 other scientific disciplines. The disciplines of science and the subdiscipline of Special Education appear on the y-axis with FGA on the x-axis. We have maintained the distinctions offered by Cleveland (1984a) and grouped Biology, Chemistry, Engineering, Geology, Medicine and Physics as the natural sciences. Computer Science, Mathematics and Statistics represent the mathematical sciences while Economics, Education, Psychology and Sociology embody the social sciences.

As suggested earlier, an FGA of 0.012 means 12 pages of journal space out of 1000 fully display data graphics. The ratio reflects the overall journal page space dedicated to data graphics. In Figure 1, the FGA ranges from 0.014, Sociology, to 0.18, Chemistry. Examining the three divisions, natural sciences range from 0.06, Geology, to 0.18, Chemistry; mathematical sciences range from 0.019, Mathematics,

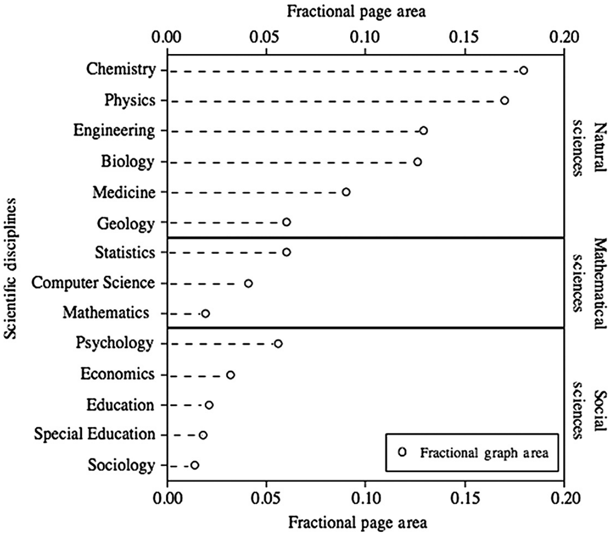

Figure 1. Fractional graph area of scientific disciplines and the subdiscipline of Special Education.

to 0.06, Statistics; and social sciences range from 0.014, Sociology, to 0.056, Psychology. Figure 1 shows the natural sciences have a higher FGA than both the mathematical and social sciences. A comparison of FGA between the disciplines in the mathematical and social sciences reveals no appreciable differences.

Special Education has an FGA of 0.018, placing it in the range of the social sciences. More specifically, the FGA of 0.018 positions Special Education near the bottom of social science disciplines, between Sociology and Education. As a subdiscipline, Special Education has an FGA, 0.018, very close to the discipline of Education, 0.021. The difference of 0.003 between Special Education and Education means both social sciences communicate their findings by means of data graphics similarly.

Data graphics and tabular displays within journals representing Individuals with Disabilities Education Act (IDEA) disability categories

Figure 2 shows another dot chart illustrating the FGA and FTA of the disability categories contained in IDEA. The y-axis shows journals that represent IDEA categories, along with multi-category, as described in the section 'Methods'. The x-axis presents the fraction of page space dedicated to data graphics, FGA noted by the solid dots and tabular displays (FTA) indicated by the open dots.

The Special Education disability categories, starting with orthopaedic impairments and progressing upward to hearing impairments and deafness, occur in a rank order by FGA. FGA ranges from 0.007 to 0.035. Also included in Figure 2, each disability category has a corresponding FTA. FTA refers to the amount of page space journals use to communicate through tabular displays of data. While not rank ordered within Figure 2, FTA ranges from 0.027, orthopedic impairments, to 0.058, emotional disturbance. As apparent from Figure 2, all disability categories have higher FTAs than FGAs. Overall, FGA and FTA have means of 0.018 and 0.041, respectively.

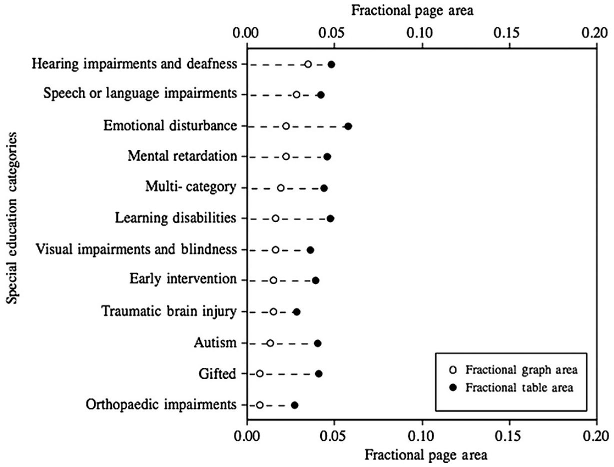

Figure 2. Fractional graph and table area of the representative journals comprising Special Education categories.

The dot chart in Figure 2 also shows a relationship between FGA and FTA. As FGA increases, the solid dots depicting FTA also increase, albeit more variably than FGA. Using a Pearson's *r*, FGA and FTA have a 0.54 correlation, which suggests a strong positive relationship. In other words, as journals in disability categories devote more page space to graphical displays of data, they also tend to allocate more page space to tabular displays of data.

Data graphics and tabular displays usage over time within Special Education

Figure 3 shows the trends of FGA and FTA for all included Special Education journals. The data range in five-year increments from 1989 to 2004. FTA has a higher level than FGA. Both sets of data have a stable but negligible trend. For FTA, the first and last data points differ but only by 0.001 (i.e. 0.042 in 1989 to 0.043 in 2004). Similarly, FGA varies by only 0.002 (i.e. 0.020 in 1989 to 0.018 in 2004).

Based on the 15-year sample, the data show no significant changes in how the 29 Special Education journals have communicated data over time. Data graphics, measured by FGA, have accounted for page space approximately equal to 18 of every 1000 journal pages. Tabular displays of data, measured by FTA, have maintained a ratio of 43 of every 1000 journal pages. Special Education journals have communicated and continue to communicate data more with tables than data graphics.

Discussion

In the current survey of Special Education journals, we ask three research questions. First, how does the subdiscipline of Education, Special Education, compare to other disciplines of science? Second, in the subdiscipline of Special Education, how do the 13 IDEA disability category subfields communicate their data in regards to data graphics and tabular displays? And third, has the use of data graphics and tables changed over time within Special Education?

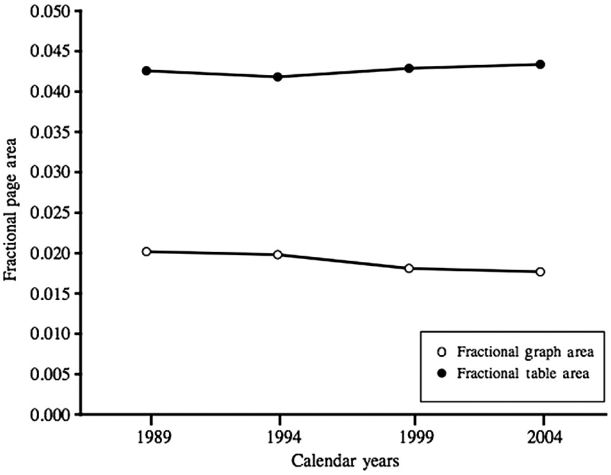

Figure 3. Fractional graph and table area for all Special Education journals measured across a 15-year span.

Special Education and disciplines of science

Cleveland's (1984a, p. 261) first sentence in his seminal article describing FGA began with a compelling statement: 'Graphs are vital for communication in science'. So reliant have scientists become on the use of visual displays of data, data graphics not only distinguish science from non-science (Latour, 1990), but also demarcate soft from hard sciences (Arsenault et al., 2006; Best et al., 2001; Cleveland, 1984a; Kubina et al., 2008; Smith et al., 2000, 2002). Scientists favour data graphics' capability to communicate data instantaneously by visually depicting trends, showing conspicuous and subtle patterns, and relating similarities and differences.

As shown in Figure 1, the disciplines in the natural, mathematical and social sciences vary in the amount of page space allocated for graphical displays of data. The natural sciences dedicate the most page space in their journals. On average, the natural sciences dedicate three to four times as much space as the mathematical and social sciences, respectively. Stated differently, the disciplines in the natural sciences place a premium on data graphics to communicate evidence.

With the advent of laws like the No Child Left Behind Act of 2001, however, the field of Education in countries like the USA now must operate under federal legislation that, '... exalts scientific evidence as the key driver of educational policy and practice' (Feuer, Towne, & Shavelson, 2002, p. 4). Figure 1 shows that Special Education and its parent discipline Education rely less often on data graphics as a medium for presenting evidence. FGA does not speak to the trustworthiness of scientific evidence but how the discipline shares data. And in a climate of improving Special Education through a framework of science (e.g. Odom et al., 2005), the FGA for the Special Education discipline does not indict the discipline on the goodness of data but suggests it should closely inspect the practices for how it communicates evidence.

Disability categories of Special Education

Figure 1 shows the lowest degree of FGA occurring with Sociology, and then Special Education. Does a low degree of FGA infer that Special Education does not have as much evidence as the other sciences? While data graphics, in many forms, have benefitted the advancement of knowledge in science, other methods exist to show data, notably, tabular displays of data. Best et al. (2001) and Smith et al. (2002) have shown that social sciences tend to communicate evidence more with tables than graphical displays of data. Therefore, we divided Special Education into its constituent parts and measured both FGA and FTA.

Even given the diverse categories of disabilities in Special Education, journals representing each category use more tables to communicate evidence than data graphics. In all 13 Special Education categories, FTA overshadowed FGA. For instance, emotional disturbance has the highest FTA of 0.058 and an FGA of 0.022. By combining the two ratios, emotional disturbance has a total of 0.08 or 8% of the page space devoted to tables and graphs. Of the total display of evidence, data graphics and tables, the majority or approximately 75% of the total display goes to tables. Figure 2 makes obvious the preferential mode of communicating scientific evidence for Special Education: tables.

The data for FTA and FGA demonstrate that Special Education does have more evidence than shown by FGA alone. Relatedly, Arsenault et al. (2006) examined the use of inscription devices (e.g. graphs, tables, equations and non-graphic illustrations) in journals in seven scientific disciplines. They found the number of inscriptions for the three soft sciences, Sociology, Economics and Psychology, was approximately the same as the number of inscriptions for the hard sciences, Medicine, Biology, Chemistry and Physics. Arsenault et al. (2006, p. 394) state that, 'This finding suggests little overall difference between the hard and soft sciences in general reliance on inscriptions, implying that whatever differences exist in inscription use lie more in the types used than in the overall rate of use…'

While our study did not include the measurement of equations and non-graphic illustrations (e.g. photograph, flow chart) like the Arsenault et al. (2006) study, Figure 2 suggests Special Education as a social scientific discipline does communicate its evidence more with tabular displays of data than graphics. The data in Figure 2 propose a more sombre view when compared to the natural sciences in Figure 1. Specifically, Arsenault et al. (2006) found an equivalency between all inscriptions used; we did not. Even by adding the FTA and FGA for all of the disability categories (range = 0.034–0.08 total data display), these combined numbers surpass only the FGA of Geology. In other words, the FGA of the other natural sciences exceed the total display of evidence in Special Education.

The correlation of 0.54 between FGA and FTA in the Special Education journals does offer an interesting insight. Best et al. (2001) in Psychology and its subdisciplines and Kubina et al. (2008) in behaviour analysis and its subdisciplines showed an inverse relationship between FGA and FTA. As page space devoted to data graphics increased, page space devoted to tables decreased. The inverse relationship shows softer subdisciplines rely more on tabular displays of data than harder subdisciplines. Our correlation indicates a different relationship: as journals devote more page space to data graphics, an increase also occurs with tables. The data suggest Special Education does not have hard and soft subdisciplines. Further, subdisciplines that encourage a higher use of inscription devices do so not only for tables, but also for data graphics.

The use of tables for communicating scientific evidence, however, has not met with the same enthusiasm as data graphics. For example, the Farquhar brothers famously wrote:

> The graphical method has considerable superiority for the exposition of statistical facts over the tabular. A heavy bank of figures is grievously wearisome to the eye, and the popular mind is as incapable of drawing useful lessons from it as of extracting sunbeams from cucumbers. (Farquhar & Farquhar, 1891, p. 55)

In the time since the Farquhar brothers' disdainful commentary on tables, nothing has changed in regard to the ultimate effectiveness of tables. Tables 'are a rhetorically primitive means of data representation, lacking the readability of graphs as well as their power to promote theoretical integration and mobilise consensus among competing camps of scientists' (Smith et al., 2002, p. 753). While tables can play a role in data presentation, the degree to which Special Education has elevated table use as the preferred means of communicating evidence speaks of a critical limitation in theory building and defending knowledge claims of the complex subject matter of the discipline.

Odom et al. (2005, p. 139), as an example, suggested two features of Special Education research that make it 'the hardest of the hardest-to-do science'. First, IDEA has 12 eligibility categories, each possessing extraordinary variability. Second, the Education context spans from general and Special Education settings to non-public environments, such as the home, hospitals or the workplace. To comprehend the complex scientific data generated by experiments, Special Education researchers will most often share their evidence through tables, which extend only the most basic and unsophisticated numeric analysis. Data graphics that could help the discipline discover the deep structure and characteristic patterns of human behaviour have not reached a threshold of use found in the natural sciences (Figure 1), nor have any of the disability categories (Figure 2) shown a preference for data graphics over tabular displays of data. Therefore, the rich sources of information most useful for understanding the complex subject matter of Special Education have a small presence in the collective communicative and analytical medium.

Special Education fractional graph area (FGA) and fractional table area (FTA) across time

Figure 3 answers the question, 'Has the use of data graphics and tables changed over time within Special Education?' For the 15-year time span covering 1989 to 2004, FGA and FTA do not significantly change for all identified journals. The trends for FTA and FGA show almost no change with both measures having inappreciable upward and downward slopes. The variability also appears negligible for both data paths. The lack of an increasing or decreasing trend coupled with almost non-existent variability strongly suggest no change in the page space devoted to data graphics and tabular displays of data has occurred over the past 15 years. Furthermore, the data patterns do not suggest a change will occur in the future.

The evidence for graph and table use within Special Education only describes past and current data; the current data do not indicate why or what variables account for the minimal use of data graphics. Editorial policy seems a logical place to start because it contributes to the preferred substance, style guidelines and displays of evidence. *The Journal of Special Education* (2009), for example, states that under requirements for reports of empirical research, 'Tables and figures should be used judiciously' (¶ 1). Additionally, the American Association on Intellectual and Developmental Disabilities [AAIDD] (2009) suggests that 'tables and figures should be kept to a minimum'

(Numerical and Illustrative Presentations and References, ¶ 1) for submissions to the *American Journal on Intellectual and Developmental Disabilities.*

When editorial policy directs authors to constrain evidence, a number of questions arise. Perhaps the most significant pertains to policy. Does it have its roots in budget constraints for printing the journal, or does the policy reflect Special Education's culture of evidentiary standards? Scientific disciplines that embrace graphical expression have data graphics permeated in their practice from the laboratory, fieldwork, theses and dissertations, to lectures, conference presentations and journals. As Latour (1990, p. 36) observed, inscription devices have rhetorical and polemical advantages for those who use them: 'You doubt what I say? I'll show you'.

Whether editorial policy impels authors to present evidence with words, tables, or limited graphics, or authors come from traditions that value words and tables over data graphics, the present research cannot answer. But the FGA and FTA of Special Education do add to the thoughtful conversation surrounding the scientific methods and evidence-based practices necessary for improving all of the methodologies used in the discipline (Brantlinger, Jimenez, Klingner, Pugach, & Richardson, 2005; Gersten et al., 2005; Horner et al., 2005; Odom et al., 2005; Thompson, Diamond, McWilliam, Snyder, & Snyder, 2005). Scientific progress in Special Education will advance not only from an assortment of high quality methods, but also how the discipline views and communicates evidence.

Future research directions

The sample size used in the present survey incorporated 29 journals, over 8500 graphics and tables, and spanned 15 years. Future research could broaden the scope to include more or different journals and expand the time frame. A survey of the form and diversity of data graphics used in Special Education journals would inform the discipline with data showing current usage of graphical types (e.g. data maps, time series and relational graphics). Furthermore, such a survey and its subsequent results might inspire teachers and researchers to use new graphical innovations during practice and applied experimentation. Still, future research might also explore the quality of data graphics present in Special Education journals in the manner of Cleveland (1984a) by focusing on graphic construction, image quality, explanations accompanying graphics and visual discrimination of graphic elements.

Conclusions

As scientific disciplines grow, a distinguishing feature of their maturation entails the increasing dependence on data graphics. Data graphics serve multiple functions in the scientific process, including the discovery of new facts and fact construction, the stabilisation and summarisation of empirical relationships and theory formation, theory testing, rhetorical inducement and theoretical integration (Latour, 1990; Smith et al., 2000). The presence and use of quantitative data alone does not set the social sciences apart from the natural sciences. If it did, Economics would top all of the sciences (Machlup, 1961, as cited in Smith et al., 2000).

The distinguishing feature of the natural sciences manifests itself in the persistent and pervasive use of data graphics. The FGA data from the present analysis show graph use in Special Education places it near the bottom of all scientific discplines. The use and presence of data graphics also shows the close relationship Special

Education has with its parent discipline Education's predisposition for a minimum amount of graphical communication. Additionally, the FTA usage comports with previous research and suggests that while the field may have a commitment to empiricism, its preferred medium for explaining, interpreting and analysing data occurs most often with tables.

Over the 15-year period of analysis, the Special Education journals surveyed have shown stable trends for both FGA and FTA. The results of this survey and similar research (Arsenault et al., 2006; Cleveland, 1984a; Kubina et al., 2008; Smith et al., 2002) add to the urgent dialogue in the Special Education field, debating how science should guide practice (Odom et al., 2005). The data from the present review and analysis support the idea that, 'visual modes of thought and communication are at least as important to science as the logocentric modes of language, logic and Mathematics' (Arsenault et al., 2006, p. 417).

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