Mapping the Field of Statistics Education Research in Search of Scholarship

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Abstract
This paper is intended as a contribution to the advancement of scholarship in the field of statistics education, which directly links with the scholarship of teaching and learning. It is apparent from the literature, that statistics education research, as an interdisciplinary field, does not rely on a single tradition of research methodology. There are different research backgrounds, different research methods are used, studies have different foci and different outcome variables are studied. What constitutes research in statistics education is therefore still a fundamental issue, with a consequent call for more research in this field. The present study attempts to identify the major themes of statistics education research in order to provide an overview of its current thematic nature. Twenty-four doctoral dissertations as well as 138 articles in three specialist statistics education journals, published between 2005 and 2009, were analyzed regarding their key themes and topics. The frequency of occurrence of the key themes is summarized.

We found that the teaching and learning of statistics was the most popular theme or topic. In particular, there is a growing network of researchers interested in studying the development of students’ statistical reasoning. Only 15% of the literature was dedicated to studies on the use of information communications technology (ICT), with the relevant studies reflecting the popularity of JAVA Applets and simulation tools. A smaller portion of the literature was devoted to course design and non-cognitive factors.

This study provides a framework for understanding current developments in statistics education research and suggests structure to the field, making it easier for future researchers to become acquainted with the discipline. In this way a contribution is made in furthering scholarship in statistics education.

Keywords
Scholarship, Statistics education, Statistics education research, Statistical themes, teaching and learning

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We found that the teaching and learning of statistics was the most popular theme or topic. In particular, there is a growing network of researchers interested in studying the development of students’ statistical reasoning. Only 15% of the literature was dedicated to studies on the use of information communications technology (ICT), with the relevant studies reflecting the popularity of JAVA Applets and simulation tools. A smaller portion of the literature was devoted to course design and non-cognitive factors.

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Keywords: scholarship; statistics education; statistics education research; statistical themes; teaching and learning

Introduction
The idea of a scholarship of teaching and learning has won much ground over the last two decades, particularly since the publication of Boyer’s work in 1990. Boyer’s four types of scholarship include the scholarship of teaching which he describes as a way of transmitting knowledge as well as to transform and extend it (Boyer, 1990).
The authors intend the research presented in this article as a contribution to scholarship in the field of statistics education, which directly links with the idea of a scholarship of teaching and learning. The point of departure is the definition of Carolin Kreber (2005) who describes the scholarship of teaching and learning as consisting of

- a deep knowledge base of the discipline (statistics in this case)
- a deep pedagogical base (generally as well as related to statistics specifically)
- an inquiry orientation
- deep reflectivity
- peer review and publication

According to this definition the scholar in statistics education builds on a deep statistical knowledge base, continually gains pedagogical knowledge on the best ways to improve statistics education, deliberately inquires into the teaching and learning of statistics, and reflects on own educational practices. Furthermore, the scholar should continuously reflect on successes, deliberately undertake research on own practices, gain knowledge in this way, and ultimately share the gained knowledge and expertise with the statistics education community in publications.

This article mainly contributes to the "deep pedagogical base" as indicated in the definition by Kreber. In dealing with the challenges of teaching scholars can benefit from deep or thorough knowledge of findings from research on and study of statistics education. Such knowledge can also stimulate an inquiry orientation and deep reflectivity leading to systematic research and publication – as set out in the definition.

The role of knowledge from literature in the building of a knowledge base is emphasized for the developmental road towards the scholarship of teaching and learning distinguished by Weston and McAlpine (2001). In the first phase Weston and McAlpine regard reading as important for the development of an understanding of the principles underpinning teaching and learning. In the second phase an increased understanding of the complexity of teaching and learning develops, while the scholar, in a third phase, displays comprehensive knowledge of research and literature on teaching and learning (also in a specific field of study).

There is however a universal problem. Bitzer (2006) points out that “...no or little recognition is given to research into teaching, developmental efforts and publishing on teaching within and across disciplines”. Trigwell and Shale (2004) argue that, although it is the responsibility of scholars to share the results of their investigations, the sad truth is that many departments and institutions do not count ‘pedagogical scholarship’ as part of the faculty member’s scholarly production. Interestingly, the term ‘scholarship of teaching and learning’ is not used frequently in science publications, including mathematics, statistics, and computer science. Various authors (Bitzer, 2006; Elton, 2008) pay attention to the situation. Elton, for example, refers to the “dichotomy between research and teaching” as a contributing factor to the ‘unfriendly climate’ and also mentions that most lecturers in the pure disciplines have only received education in their discipline (and not in teaching and learning, whether generically or in the discipline). Intending to assist the young scholar in statistics education the authors attempt to organize the diverse range of studies pertaining to this field. The findings should, however, also be relevant to the larger statistics and SoTL communities.

Given the diversity of disciplines, methodology, and orientation of the studies that can be classified under the heading of 'statistics education research’, defining what constitutes research in statistics education is still a fundamental issue. In this article, therefore,
statistics education as a research field in general is examined, together with an effort to suggest a categorization that may bring some clarity on the nature of the field. Furthermore, the article seeks to map and analyze the field of statistics education research as it has established itself during the last half of this decade. Since the first studies on the teaching and learning of statistics appeared in the literature, there has been a proliferation of studies across many disciplines, as well as new scientific conferences and publications devoted to research in statistics education (Garfield & Ben-Zvi, 2007). Consequently, a systematic analysis of these studies is indicated in order to summarize both the present situation and emerging trends in the field of statistics education research. A total of 138 research articles published in the five-year period from 2005 to 2009 in three statistics education journals (Statistics Education Research Journal, Journal of Statistics Education and Teaching Statistics), as well as 24 doctoral dissertations indexed by the International Association for Statistical Education between 2005 and 2009 were analyzed.

In the investigation a content analysis procedure was employed. The studies included in the research were analyzed according to a number of key questions of which the following are addressed in this report: What are the main variables of interest? What are the key themes and topics of the research articles and dissertations?

We briefly discuss the sources used, the data collection method, and the analysis procedures. This is followed by the findings of the project with respect to the key themes and topics of the research articles. Finally, some conclusions and limitations of the study are provided.

**Mapping the Field of Statistics Education Studies and Research**

In this section, we provide an empirically based mapping of statistics education research from 2005 to 2009. In order to map the field of interest, studies included in the research are analyzed according to their key themes or topics.

**Previous Contributions**

We could only locate one attempt in the literature that organize or classify statistics education research in terms of themes/topics. Becker (1996) analyzed the content of publicly accessible printed literature on the teaching of statistics, examining the topic presented and whether empirical evidence is used to support the claims that are made. She presented an analysis of the content of 501 references and 29 dissertations identified by three computerized databases: the ERIC database, the PsycINFO database, and the Expanded Academic Index (ACAD). Becker suggested five major themes/topics:

1. **Computer use** (including computing in general, computer assisted instruction, software, and simulation activities).
2. **Teaching materials** (including activities, lessons, materials, texts and tools).
3. **Teaching approaches** (including teaching strategies and writing exercises).
4. **Individual differences** (including gender and aptitude).
5. **Discussions** (including general discussion, course descriptions, and curriculum issues).

Becker (1996) acknowledges that she did not seek out the literature on what might be called statistical thinking or statistical reasoning. Furthermore, since the study is now almost 15 years old, recent developments have not been taken into account. For the above two reasons, the authors attempted to identify the most recent trends/topics (2005–2009) without a predetermined exclusion of any type of study. It would also be possible to determine whether and how emphases have changed since the first half of the 1990’s.
Sources
All relevant research articles published in three statistics education journals (Statistics Education Research Journal, Journal of Statistics Education and Teaching Statistics) between the years 2005 and 2009, and doctoral dissertations indexed by the International Association for Statistical Education, also from 2005 to 2009, were selected to serve as the corpus of this investigation. The three journals were selected because of their popularity among academics and researchers in statistics and because these journals aim to attract researchers from various disciplines whose work relates to teaching and learning statistics (Zieffler, Garfield, Alt, Dupuis, Holleque & Chang, 2008).

The Statistics Education Research Journal (SERJ) is a peer-reviewed electronic journal of the International Association for Statistical Education (IASE) and the International Statistics Institute (ISI). SERJ focuses on all educational levels and seeks to advance research-based knowledge to improve the teaching, learning, and understanding of statistics or probability. Garfield et al. (2007) reported that the SERJ, which was established in 2002, is the first dedicated scientific journal for the statistics education discipline in which high-quality research is published.

The Journal of Statistics Education (JSE) is an electronic journal focusing on postsecondary statistics education. However, the journal also disseminates knowledge for the improvement of statistics education at other levels, including elementary, secondary, postgraduate, and workplace education. The aim of the journal is to publish articles that enhance the exchange of a diversity of interesting and useful information among educators, practitioners, and researchers around the world.

Teaching Statistics is a British journal and first appeared in 1979. The journal focuses on teachers of students aged 9 to 19 and includes articles on teaching statistics as a specialist subject. Furthermore, Teaching Statistics seeks to help teachers of various disciplines, such as biology, business studies, economics, geography, mathematics, sciences, and social sciences by showing how statistical ideas can illuminate their work.

The doctoral dissertations reviewed here were obtained from the website of the International Association for Statistical Education (IASE) (http://www.stat.auckland.ac.nz/~iase/publications/dissertations/dissertations.php). The IASE is a section of the International Statistical Institute (ISI) and is the main international association devoted to improve and extend statistical education at all educational levels. The webpage contains an extensive collection of dissertations since 2000 in the area of statistics education.

Data Collection and Analysis Procedures
The data were collected through a documentary analysis of 138 research articles selected from three statistics education journals and 24 doctoral dissertations in statistics education. (To prevent overlapping of research and possible double coding, we made certain that our selection of articles did not include research emanating from the dissertation sample.)

The article and dissertation analysis employed content analysis procedures in which themes and topics were chosen for examination while their frequency of occurrence within the text was recorded. Tull and Miller (2009) offer a broad definition of content analysis as follows: “Content analysis allows for the construction of a thematic understanding of data in categories and presents data in a manner that emerges from a raw or unfiltered form to something with meaning that can inform consumers of research”. This kind of analysis is used to determine the presence of certain words, concepts, themes, and methods within texts to quantify their presence in an objective manner. It is also useful for examining
trends and patterns in documents and its reliance on coding and categorizing of the data makes the technique particularly rich and meaningful (Stemler, 2001).

There are two general categories of content analysis: conceptual analysis and relational analysis. The present study used conceptual analysis, where a concept was chosen for examination and the frequency of its occurrences within the articles and dissertations recorded. The articles and dissertations were coded into manageable content categories through open coding. Open coding refers to that part of the analysis that deals with the labeling and categorizing of phenomena as indicated by the data. This was followed by axial coding with data connected in new ways and selective coding with the identification of core categories.

By following the above route, the themes or topics addressed by the 162 documents were identified and coded. This was a time-consuming process of reading, making sense of the data, coding and organizing. This was partially done manually and partially computer assisted (Excel). In the classification process the researchers were led by three sources (cf. McMillan & Schumacher, 2001:467), namely concepts, themes and categories used by other researchers in prior studies (e.g. Becker, 1996; Tight, 2003; Bitzer & Wilkinson, 2009); their own prior knowledge (having lectured in statistics and mathematics/science education respectively for many years); and the data itself. The coding and categorization processes were consequently of an inductive as well as a deductive nature.

Each document was assigned as many codes as needed to describe its themes or topics using the most detailed level of coding possible. For example, studies that investigated computer assisted teaching as well as students' reasoning about a concept would receive the topic code CAT, CR (CAT = computer assisted teaching and CR = concept reasoning). Multiple topic codes were assigned to many of the documents. All codes were listed and similar and related codes were grouped to arrive at a smaller number of key themes or topics. Because the themes or topics showed overlapping in many cases, a series of sub-themes was identified to ultimately assign only one dominant code to each document. Furthermore, no different weighting was given to published material over doctoral dissertations.

Results

The main themes/topics identified are presented according to the distribution of main- and sub-categories, followed by a brief discussion of each main category. The most frequently covered topic in each journal and in the doctoral dissertations is identified here.

The six main categories and sub-categories of topics are indicated in Table 1. The number of occurrences (frequency) and percentages of the categories are also presented. For simplicity, all percentages reported in this study were rounded to the nearest whole number.
TABLE 1. Categories of themes/topics regarding statistics education research in the period 2005-2009 (N = 162)

<table>
<thead>
<tr>
<th>Main Categories</th>
<th>Sub-categories</th>
<th>f</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Teaching and learning</td>
<td>• Teaching activities</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>• Teaching strategies (e.g. experiential learning, co-operative learning, problem-based learning)</td>
<td>16</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>• Writing exercises and real data</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>47</td>
<td>29</td>
</tr>
<tr>
<td>2. Statistical reasoning</td>
<td>• Reasoning about a statistical concept</td>
<td>36</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>• Methods to assess statistical reasoning</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>40</td>
<td>25</td>
</tr>
<tr>
<td>3. Non-cognitive factors (e.g. students’ feelings, motivation, anxieties)</td>
<td>• Instruments to assess non-cognitive factors</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>• Role of non-cognitive factors in the learning of statistics</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>17</td>
<td>10</td>
</tr>
<tr>
<td>4. Use of Information Communications Technology (ICT)</td>
<td>• Computer assisted teaching</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>• Description or comparison of software packages</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>• Simulation methods</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>• Online education</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>24</td>
<td>15</td>
</tr>
<tr>
<td>5. Course design</td>
<td>• Course design/redesign</td>
<td>14</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>• Course materials</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>• Service-learning courses</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>20</td>
<td>12</td>
</tr>
<tr>
<td>6. Non-empirical studies</td>
<td>E.g. discussion papers, literature reviews and textbook evaluations</td>
<td>14</td>
<td>9</td>
</tr>
</tbody>
</table>

This categorization may be usefully compared with that proposed by Becker (1996). Becker’s acknowledgement that she did not seek out the literature on statistical reasoning confirms the need for this new category, which proved to be the second most popular topic of research in the study. What Becker termed Individual differences, appears here as Non-cognitive factors, mainly because of the amount of attention factors such as student motivation, feelings, anxieties and many more have been given in recent years. These factors necessitate a new category separate from the cognitive (the statistical reasoning). Becker’s Teaching materials is now subsumed under the more encompassing Course design in our listing. Her Teaching approaches appear as Teaching and learning to indicate the change towards the viewpoint of student learning as an inseparable part of teaching (as also observed in the term SoTL). Teaching and learning and Course design have also been indicated as main categories in the classification of higher education research by Tight (2003) and Bitzer and Wilkinson (2009). What Becker labeled as Computer use is replaced by Use of Information Communications Technology (ICT), a much broader concept that includes the traditional computer assisted technologies as well as the more recent and rapid growing range of digital communication technologies. The sixth category, Non-empirical studies, relates to but is regarded a broader concept than Becker’s Discussions.

The data itself, as well as the knowledge of the researchers, gave rise to the refinement of the sub-categories in the listing. However, in accordance with the views of Tight (2003) the researchers do not claim that this is a definitive listing, but would rather describe it as indicative and useful, and acknowledge that inevitably some overlapping between the
categories and sub-categories occurred. More clarity on the nature of the sub-categories is provided below.

- The **Teaching and learning** category includes studies about teaching activities, teaching strategies, and the use of writing exercises and real data to improve student learning. Activities are mainly performed to illustrate a statistical concept. However, activities involving ICTs are not included in this category. Teaching strategies are methods implemented to help students to learn more successfully and to enable them to progress from dependent to independent learners. Experiential learning, co-operative learning, problem-based learning, constructivist teaching, and thematic teaching are strategies that are found in this category. Again, strategies involving ICTs are not included here. Real data engage, and may even transform, student understanding of statistical methods or reasoning. Studies that explore and discuss the use of real data sets and writing exercises (displaying, analyzing and interpreting real data) are included in this category.

- In the category of **Statistical reasoning**, studies that focus on students’ statistical reasoning about important statistical ideas and concepts are included. Statistical reasoning comprises the way students reason with statistical ideas and make sense of statistical information. It may involve connecting one concept to another or may combine ideas about data and chance (Garfield et al., 2007). Statistical reasoning also means understanding and being able to explain statistical processes, and being able to interpret statistical results. Studies included in the first sub-category (reasoning about a concept) investigate the development of particular types of statistical reasoning using specific activities and tools. Studies that focus on assessing students’ statistical reasoning are included in the second sub-category. The development of these instruments and discussions about the different types of instruments (quantitative and qualitative) are also included in this sub-category.

- The **Non-cognitive factors** category consists of studies that investigate students’ beliefs, feelings, attitudes, motivation, and anxieties related to statistics. The use of humor in class and studies related to gender differences are also included in this category. These studies either develop or describe instruments to assess non-cognitive factors or investigate the role of non-cognitive factors in the learning of statistics.

- Four sub-categories emerged from the **Use of ICT** category. First, computer assisted teaching refers to studies that discuss and develop computer-based activities that act as a component integrated with a traditional didactic course. Second, computer software packages include studies that describe or compare software designed for the purpose of performing statistical analysis. Third, simulation methods refer to studies that describe or develop a simulation tool to illustrate statistical ideas through simulation to construct a deeper understanding of underlying concepts. Fourth, online education includes studies about online courses that range from the use of web-based applications in traditional courses to full-blown online courses without face-to-face contact. This category is obviously far from being exhausted, and it can be expected that future studies may report, inter alia, on the use of mobile devices such as mobile phones, ipods and clicker systems, and a wide range of interactive Web 2.0 technologies (all which may need additional sub-categories).
• The Course design category includes studies regarding undergraduate and postgraduate course design, curriculum development (including statistics within the school mathematics curriculum), the development of new course materials, and service-learning courses. Studies investigating the effects of basic numerical and graphical skills on students’ level of mastery of statistical concepts also fall under this category.

• Studies in the Non-empirical studies category include discussions on statistical reasoning, statistical concepts, statistical terms, misconceptions about a concept, student experiences of a course, and class preferences or teaching styles (thus discussion papers). Textbook evaluations and literature reviews are also included here. These articles provide a wealth of ideas for developing statistical reasoning, improving student experience, and reducing misconceptions about statistical concepts.

Journals Categorized by Topics/themes
Table 2 presents the counts of the overall topics in the literature for each of the three journals and the doctoral dissertations separately.

Statistical reasoning was the most frequent topic covered in the SERJ and the doctoral dissertations. The fact that almost half (48%) of the articles in the SERJ and more than half (63%) of the doctoral dissertations were about statistical reasoning indicates a great interest in this topic. Topics that emerged from the doctoral dissertations in this regard are, for example “How do college students reason about hypothesis testing in introductory statistics courses?”, “Investigating elementary school students’ reasoning about distributions in various chance events”, “A longitudinal investigation of the development of College students’ reasoning about bivariate data during an introductory statistics course”, and “Statistics students’ reasoning when comparing distributions of data”. The fact that the SERJ aims to publish high quality research and that doctoral dissertations also require high quality research was perhaps the main reason why the complex topic of statistical reasoning appears most frequently in the two sources.

The majority of the articles in both the JSE and Teaching Statistics covered the topic of teaching and learning; 40% of the articles in the JSE and 47% of the articles in Teaching Statistics examined this topic. The aim of these two journals is to publish articles on teaching statistics as a specialist subject, which may explain the high prevalence of the topic of teaching and learning. We also note that the second most frequent topics in both journals were the use of ICT and course design.

While the three journals may be open to publishing articles on most aspects of statistics education, researchers working on particular themes should be able to get a good idea of the most likely journals to target.
TABLE 2. Frequency of topics covered by each source

<table>
<thead>
<tr>
<th></th>
<th>SERJ</th>
<th>JSE</th>
<th>Teaching Statistics</th>
<th>Doctoral Dissertations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teaching and learning</td>
<td>6</td>
<td>32</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Statistical reasoning</td>
<td>20</td>
<td>4</td>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td>Non-cognitive factors</td>
<td>4</td>
<td>8</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Use of ICT</td>
<td>4</td>
<td>14</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Course design</td>
<td>2</td>
<td>15</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Non-empirical studies</td>
<td>6</td>
<td>8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>42</strong></td>
<td><strong>81</strong></td>
<td><strong>15</strong></td>
<td><strong>24</strong></td>
</tr>
</tbody>
</table>

Discussion of Results

In this section the results are discussed according to the different categories identified (see Table 1).

Teaching and Learning

Teaching and learning was the most common topic category. It appeared in about 29% of the documents, and within this category the most common topic was teaching activities, followed by teaching strategies. Writing exercises and the use of real data were mentioned or investigated in only a few studies.

Of the 47 documents coded as pertaining to teaching and learning, 25 (about 53%) covered the topic of teaching activities. More than half of the activity studies deal with games (8 studies) and projects (6 studies). Some interesting games emerged from the studies. Andrews (2005) presents a rich data set from the game of Ultimate to demonstrate hypothesis testing, Markov chains and logistic regression. Students can perform different types of analysis on the data as in-class activities. Sorto and White (2008) use the Gumball game activity to give students the opportunity to explore and discuss the variation which occurs in sampling, and Stephenson, Richardson, Gabrosek and Reishman (2009) describe an interactive activity that revolves around the diced-based golf game GOLO. This activity illustrates the binomial distribution, the sampling distribution, confidence intervals for proportions, and hypothesis tests for proportions. The remainder include a game to illustrate the technique of distance sampling, a game where students attempt to measure something they cannot see, a card game to reinforce basic statistical concepts, a game involving students attempting to toss a ball into a trash can from various distances, and a game with paper clips to learn how to collect and analyze data, and how to infer conclusions from data analysis.

Three types of projects were investigated: Research projects typical of the type encountered in statistical practice, from the formulation of a researchable question to the analysis and interpretation of the results are described in a few studies. Gunaratna, Johnson and Stevens (2007) discuss student participation in real consulting projects to help them develop statistical consulting skills and to allow them to apply statistical concepts. They also discuss classroom material to solve real problems. Another project illustrates how doctoral students developed a follow-up survey for teacher preparation programs to help them gain the skills needed to develop sound assessment instruments. The remaining 11 activity studies are very diverse. These activities include demonstrations, experiments and assignments.
Teaching strategies are covered in 14 research articles and in two doctoral dissertations, about 34% of the 47 documents coded as pertaining to teaching and learning, and slightly fewer than 10% of the total. Most of these (31%) illustrate action research by teachers to improve their skills. Roback, Chance, Legler and Moore (2006) discuss the Japanese Lesson Study Principles which constitute a collaborative approach for teachers to plan, present, observe and critique classroom lessons. Through this lesson study process, teachers systematically examine both student learning and their own teaching practices. Groth (2008) gauges teachers’ perceptions of GAISE (Guidelines for Assessment and Instruction in Statistics Education) which helps to reveal both barriers and inroads to the implementation of GAISE recommendations in the classroom. One article reports how students identified areas of concern about their learning and how teachers and researchers identified problematic areas, while two interventions as teaching strategies to improve motivation and conceptual understanding are investigated in another study.

In another 25% of the teaching strategy studies the use of group work, co-operative learning, or individualization are examined. Three studies use visual representations (e.g. photographs and graphs) to enhance understanding and to facilitate problem solving, while the remaining articles discuss constructivism, innovation, and new illustrations in class as teaching strategies in the classroom.

Writing and the use of real data in statistics education have only recently been investigated as a component of teaching; all six studies of real data and writing have been conducted since 2007. Interesting datasets used for writing exercises are real stock market data, data collected for several hundred used motor cars, and atmospheric concentrations of chlorofluorocarbons.

**Statistical reasoning**

Statistical reasoning was the second most prevalent topic found in the documents, namely in 25% of the sources. The documents on statistical reasoning largely focused on reasoning about a statistical concept. The high percentage of documents related to this sub-category confirms this impression (90% of the 40 documents coded as pertaining to statistical reasoning examine students’ or teachers’ statistical reasoning about a specific concept). More than one-third (36%) of these documents are doctoral dissertations.

Statistical variation was the most popular statistical concept investigated (10 documents), followed by statistical inference (8 documents) and probability distributions (5 documents). Based on this analysis, reasoning about statistical inference has been investigated only recently; all studies on statistical inference (except for one doctoral dissertation) were conducted during 2008 and 2009. The majority of the studies on reasoning about other concepts were conducted from 2005 to 2007. The remaining concepts under investigation are diverse and include reasoning about statistical sampling (e.g., Noll, 2007), hypothesis testing (e.g., Kaplan, 2006), quantitative bivariate data (e.g., Zieffler & Garfield, 2009), and probability (e.g., Rubel, 2007).

Only 10% of the studies on statistical reasoning focus on the use and development of instruments to assess statistical reasoning. For example, delMas, Garfield, Ooms and Chance (2007) describe the development of the CAOS (Comprehensive Assessment of Outcomes in Statistics) test, while Lane-Getaz (2007) developed and validated the RPASS (Reasoning about P-values and Statistical Significance) scale.

**Non-cognitive factors**

Among the 17 non-cognitive studies, only five (about 30% or 3% in total) discuss or develop instruments to assess non-cognitive factors. Of these, two are doctoral
dissertations. One dissertation describes the development and validation of a scale for measuring instructors’ attitude toward concept-based teaching of introductory statistics at the tertiary level (Hassad, 2007), and the other dissertation describes the development of a Statistics Anxiety Measure (Earp, 2007). Among the research articles, an Attitude Toward Research scale is created, and The Survey of Attitudes Toward Statistics as well as the Statistical Reasoning Assessment are discussed.

In seventy percent of the non-cognitive studies the role of non-cognitive factors in the learning of statistics are investigated (3 of the 12 studies were doctoral dissertations). Attitudes toward statistics are covered in four (one third) of the studies (e.g., Vanhoof, Sotos, Onghena, Verschaffel, Van Dooren & Van den Noortgate, 2006). The effect of humor and motivational constructs are examined in a few studies, while the effect of perfectionism, anxiety, gender, and race are investigated in single studies only.

**Use of ICT**

The Use of ICT as a category formed about 15% of the literature. Nearly half (46%) of the sources in this category refer to computer assisted teaching and its effect on student learning, understanding, and performance. Almost two-thirds (64%) of the studies in this sub-category were conducted during 2008 and 2009. It seems that JAVA Applets as a technological tool to illustrate concepts such as ANOVA, the central limit theorem, and the law of large numbers are quite popular.

A variety of aspects of computer assisted teaching are studied in the remaining 13 investigations. Martin (2008), for example, uses a spreadsheet tool to illustrate F-tests, t-tests, multicollinearity and statistical power analysis. Watson (2008) uses the statistics data-visualization software TinkerPlots to develop students’ informal inference skills. Green (2007) develops a graph called Grapharti to facilitate insight into large amounts of data. Ragasa (2008) determines whether there is a significant difference in achievement between a treatment group (who made use of computer assisted teaching) and a control group (who was taught with the use of the traditional method). Only one doctoral dissertation covers the topic of computer assisted teaching and the focus was to determine whether or not various uses of technology differentially affect statistics achievement among undergraduate or graduate students (Schenker, 2007).

In only two of the 24 references (8%) coded as pertaining to Use of ICT, new statistical software is examined and discussed. Brooks and Raffle (2005) describe the Friendly Introductory Statistics Help (FISH) computer program which is easy-to-use software designed to help students learn introductory statistical concepts, while Hunt (2007) describes a new software tool called ISCUS (Individualized Statistics Coursework Using Spreadsheets) which facilitates the setting and marking of student assignments based on a substantial set of data.

In five (21%) of the 24 references in the Use of ICT category the application or development of a simulation tool is discussed. Schneider (2008) develops two applets to illustrate hypothesis testing through simulation, while Hagtvedt, Jones and Jones (2008) develops a simulation tool that encourages the experimentation with multiple confidence intervals derived from the same population. Simulation tools for the generation of various probability distributions are also discussed in a few studies.

Furthermore, online education, including web-based teaching, an online tutoring system, and the use of electronic textbooks ActiveStats and CyberStats as a web-enhanced version of the undergraduate statistical course are studied in one-quarter (25%) of the articles on the Use of ICT.
Course design

Course design formed a rather small segment (12%) of the literature and no doctoral dissertation was included in this category. More than two-thirds (70%) of the sources in this category describe changes and initiatives to freshen up the typical undergraduate courses, the design/redesign of a course, and course revision. Of these, the development of a biostatistical course is discussed in three articles and students' quantitative literacy (mathematical skills) is explored in another three articles in which it is argued for an across-the-curriculum approach to teaching quantitative reasoning (e.g., Jordan & Haines, 2006). In only 10% of the sources the development of new course materials is described (e.g., Marriott, Davies & Gibson, 2009).

In one-fifth (20%) of the studies on course design the incorporation of service-learning in statistics courses is investigated. For example, a student-run consulting program that has been serving its local community can be considered as a service-learning component of the course. Hydorn (2007) presents different models for incorporating service-learning in statistics courses while other authors identify and evaluate appropriate projects for service-learning or explore advantages of assigning a service-learning project.

Non-empirical studies

Non-empirical studies formed the smallest segment of the literature. Across the 162 references, only 14 studies (9%) were coded as non-empirical. Three articles (e.g., Pfannkuch, 2005) cover students’ reasoning about variation and variability and provide possible teaching goals as well as types of assessment tasks to improve the students’ reasoning. Students’ class preferences, their preferred teaching style, and their overall experience taking introductory statistics are discussed in two articles and another two foci on textbook evaluations. Among the textbook evaluations, a content analysis of the topics dealing with probability in a sample of textbooks aimed at learners in secondary education is carried out in one study, and tasks, exercises and activities that contain probability within middle grades mathematics textbooks are analyzed in another. Only one article is a literature review on the teaching and learning of introductory statistics at university level.

In the remaining articles topics discussed were as diverse as statistical terms and their misleading impressions, the value of possessing quantitative skills to increase student confidence, misconceptions about hypothesis tests, and methods to assess structural knowledge.

Conclusions

In this article the authors outline the major themes and topics of 138 research articles and 24 doctoral dissertations. Research studies related to statistics education published in conference proceedings and articles related to the teaching and learning of statistics published in journals from other disciplines are not included in this study. Although the sampling may be seen as a limitation, the selected journals can be regarded as among the most influential in statistics education and reflect and represent contemporary trends in the field. The categorization that is provided builds on earlier work done in statistics education and attempts to accommodate changes that have taken place over the last 15 years. Although the researchers’ interpretation may differ from that of others, the categorization is seen as indicative and also flexible enough to allow for adaptation and extension.

The most notable finding is that the topic of teaching and learning of statistics seems to be very popular among researchers in the field (see Table 1), perhaps because of the large numbers of students who enroll in introductory statistics courses as a requirement for their
degree programs. The numerous teaching activities and strategies investigated and described in the literature support this belief. Furthermore, the teaching and learning articles emphasize the students’ difficulties with learning statistics and the need to revise traditional methods of teaching. Experiences with real data are emphasized which lead to an increased demand for interesting data sets and examples.

Another significant finding of the study is the growing network of researchers interested in studying the development of students’ statistical reasoning. The statistical reasoning articles reflect the shift in emphasis in statistics education: instead of focusing on procedural understanding (formulas, computations and procedures), the emphasis is rather on the development of conceptual understanding and statistical reasoning. These articles also suggest that good reasoning about important statistical concepts can be developed by using activities and tools, given enough time and revisiting of these ideas. Both quantitative and qualitative methods of assessment have been used to study students’ reasoning abilities. However, only a few quantitative instruments are available for the assessment of statistical reasoning. More validated instruments are certainly needed to assess statistical reasoning.

The research on non-cognitive factors provides evidence supporting the effect of non-cognitive factors in learning statistics. Researchers not only investigated students’ attitudes and anxiety about statistics, or the effect of humor, motivational constructs, perfectionism and gender, but also investigated its influence on performance in statistics courses. Unfortunately, only a few instruments to assess non-cognitive factors are discussed. The non-cognitive studies also reflect a great variation in students’ expectations and perceptions of what statistics are about.

With the abundance of information communications technologies now available for use in teaching statistics, it came as a surprise that only a few studies were dedicated to this topic. The small number of articles that discussed and examined new statistical software was also disappointing. More recent studies related to the use of ICTs have examined the use of computer assisted teaching and its effect on student learning and performance. The studies reflect the popularity of JAVA Applets and simulation tools to illustrate statistical concepts.

Course design and non-empirical studies formed rather small but valuable and much needed segments of the literature. The studies on course design strongly suggest the incorporation of service-learning in statistics courses. The 24 doctoral dissertations represent statistics education matters such as the learning, teaching, and assessment of statistical methods or statistical thinking and reasoning.

The implications of this analysis for statistics education research are seen as four-fold: Firstly, examining these themes revealed the emphases in statistics education research as well as the areas in need for future study. Secondly, it offers an improved framework for understanding the development and patterning of statistics education research. Thirdly, it creates some order in the field of study by providing an overview of the current themes/topics of statistics education research. Fourthly, the background given on the nature of the research in statistics education can serve as a valuable resource for current researchers in the field and will make it easier for or stimulate new researchers to become involved in researching their own practices. Overall, the article can be regarded as an attempt to advance the scholarship of teaching and learning in the pure disciplines.
Future Research
This article covers the first part of our effort to map the field of statistics education research. We intend to continue the work and further analyze the studies according to directives such as the methods and methodologies employed; the theories and concepts covered; and the organizational or disciplinary settings where statistics education is studied.

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