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ABSTRACT

This case study describes a congenitally blind undergraduate student who successfully completed a basic statistics course. Accommodations specific to his blindness included: a textbook on tape and review tapes before examinations; a talking calculator; graphs made on Braille paper and other tactile teaching aids. Affective problems encountered included overcoming low mathematical self-efficacy while cognitive problems were classified as conceptual, computational, experiential, practical, and symbolic. Among instructional strategies successfully used to overcome these cognitive difficulties were: (1) kinesthetic explanations for standard derivation; (2) cardboard curves with rubber bands for teaching problems related to areas under the normal curve; (3) very small data sets when introducing new concepts; and (4) one memorable problem for each formula studied. Teachers and tutors of students who are blind or visually impaired are urged to choose accommodations based on the type and severity of visual disability, individualize instruction based on student preferences, and perform continuous formative assessments followed by instructional adjustments. (Author/DB)

Teaching Basic Statistics to a Student Who is Blind

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Abstract

The case study of Edward, a congenitally blind undergraduate student who successfully completed a basic statistics course, is presented. Accommodations specific to his blindness included: a textbook on tape and review tapes before examinations; a talking calculator; graphs made on Braille paper and other tactile teaching aids (e.g. distributions cut from cardboard); extensive tutoring; and oral examinations with extended time. The Nemeth Code, a system of mathematical notation developed for students who are blind, was not used because of its complexity. Cognitive and affective difficulties encountered were sometimes similar to those experienced by beginning statistics students and exacerbated by Edward's disability, and sometimes were unique. Affective problems included overcoming low mathematical self-efficacy and resolving ethical dilemmas. Cognitive problems were classified as conceptual, computational, experiential, practical, and symbolic. Some instructional strategies which were successful in overcoming these cognitive difficulties may also be useful for sighted students. Examples of these strategies included the use of: (1) kinesthetic explanations for standard deviation, (2) cardboard curves with rubber bands for teaching problems related to areas under the normal curve, (3) very small data sets when introducing new concepts, and (4) one memorable problem for each formula studied. Recommendations for teachers and tutors of students who are blind or visually impaired include: (1) basing the instructional approach on information processing theory, (2) choosing accommodations based on the type and severity of the visual disability, (3) individualizing instruction based on the preferences of the student; and (4) doing continuous formative assessments with adjustments to instruction.

Introduction

Edward is a congenitally blind business major enrolled full-time at a southern university. As a sophomore he successfully completed a basic statistics course, earning a grade of B when many of his sighted friends in the class received lower grades or dropped the class. This three-hour required course in business statistics covered principles of sampling, descriptive measures, graphic presentation of data, problems using five different distributions including the normal distribution, probability and hypothesis-testing using t-tests. In addition to this course, Edward was enrolled in the second course of a required accounting series, a macroeconomics course, and a course on management and information systems, for a total of twelve hours credit.

A review of the literature on teaching students with visual impairments yielded many articles focusing on elementary and secondary students, but few on college undergraduates. Although handbooks are available giving general pointers to college faculty on working with students with disabilities, few have specific instructional ideas by content area. Only one relevant article was found which discussed teaching mathematics to students with visual disabilities (Dick & Kubiak, 1997) and one which specifically addressed teaching statistics to them (Gibson & Darron, 1999).

Accommodations

The accommodations for Edward in this statistics class included a number of changes in instructional and assessment activities. Support for accommodations was provided by the university's Office of Disability Support Services. This office provided the teacher and tutor with general information on teaching students with disabilities and specific information on how to accomplish the specific accommodations for Edward. It also supplied needed materials such as audiocassette tapes, housed equipment and tools such as Braille label makers, provided liaison between tutor, teacher and student, and shared expertise on common problems encountered by students with visual impairments.

1) Textbook on audiocassettes. The textbook was recorded by the tutor and, at the beginning of the semester, the usual instructions for reading a textbook were followed. That is,

every word of the text and each table was read and each figure was described. During the semester, however, this procedure was adapted at Edward's request. The homework problems were omitted from the tapes and instead were done orally with the tutor. The computer exercises were also omitted because the teacher did not require them.

2) Study guides on audiocassette. Review tapes were made before each of the tests although this was not a common practice. Edward felt that the review session for each test during which the teacher worked problems requested by the students was not adequate preparation for the test. He didn't have time, however, to listen to each of the tapes on the text chapters repeatedly. Therefore a concise review tape was created which included an outline of topics covered, a reading of the definitions of all vocabulary words, a review of the example problems, and a reading of the formulae used in the chapter. This tape made it quicker and easier for Edward to prepare for the test; listening to the review tape took approximately an hour whereas listening to text tapes again would have taken eight or more hours.

3) Talking calculator. A talking calculator was lent to Edward by the Office of Disability Support Services for use during the semester. Edward used it for calculating answers to problems independently. Although it was adequate for most problems, it didn't have all the required functions and a graphing calculator was used by the tutor for more complex problems. It took less time for Edward to instruct another person which numbers and operations to enter, than to do it himself. This speed was necessary not only to make effective use of tutoring time, but also was critical during tests.

4) Raised-line drawings of graphic materials. Graphs were made as raised patterns on Braille paper which Edward could feel. Although software for scanning graphs and creating raised images had been purchased by the university, it had not yet been installed. Therefore all figures either had to be described on the tapes or created manually using tools provided by the Office of Disability Support Services.

5) Invented teaching aids. Other tactile teaching aids were constructed by the tutor to illustrate key concepts. For example, the shapes of the various distributions were cut from file folders. Edward could then feel a binomial or an exponential distribution. One caution should be

noted however. All tactile teaching aids should be smooth to the touch. Paper cuts to the fingertips can be as disabling to a Braille reader as a poke in the eye to a sighted reader. Edward emphasized that his fingertips were sensitive and necessary to his daily existence; wearing a band-aid on his finger would be like a sighted person having a patch over one eye. Therefore cutouts should be covered with felt or a similarly protective material. Another caution involved the placement of Braille labels on constructed teaching aids. Placing Braille labels too close to raised figures makes them difficult or impossible to read. The reader's fingers must be able to move smoothly and completely over the Braille letters for the label to be understood. A visual analogy for sighted persons would be writing letters very small and too close together to be understood easily.

6) Extensive tutoring. As part of the accommodations for his disability, Edward has frequently requested and received a tutor for courses requiring mathematical calculations. During this semester, he had tutors in three of his four classes. The first author served as this tutor for the statistics course and the second author was consulted on a number of occasions regarding statistical content, instructional options, and patterns in student learning. For statistics, the tutoring was scheduled one hour per day and sessions occurred four to five days per week depending on course assignments in statistics and Edward's other classes. In the past, one problem was in recruiting and keeping tutors. The most difficult problem, however, was scheduling. When he, his teachers, or his tutors were ill, adjustments had to be coordinated. During test weeks or when important projects were due, schedules were adjusted to meet those deadlines. A third problem was finding a space to meet. Because of the need for a quiet environment and the limited number of study rooms available on campus, the tutoring sessions were frequently moved to various locations.

7) Testing procedures. Assessment accommodations allowed Edward to do examination problems orally, and testing time allocation was doubled. Tests were scheduled by Edward and the teacher at a time when the tutor could attend. The one-hour tests which were taken in during the regular class period in the morning became two-hour tests taken in a departmental office on the same day in the afternoon. The tests, which were open-book and open-notes for all students,

were read to Edward. He then requested his tutor to make specific calculations. His responses were then written on the test paper by the tutor.

Unexpected factors impacted Edward's performance on these formal assessments. One factor was mental fatigue due to extended periods of mental arithmetic. After attending one or more classes requiring mental calculations, it was difficult for Edward to concentrate effectively. His performance anxiety exacerbated this difficulty. Another factor impacting his performance was the presence of distractions. Sometimes these distractions were due to physical intrusions into the testing space; one test was administered in the departmental copy room. At other times, these distractions were due to auditory interruptions. A vacant office in the business building near the professor's office could be used, but even conversations in the hallway outside with a closed door could slow calculations or prevent the complete concentration needed to work the problems correctly.

8) Nemeth Code. The Nemeth Code, a system of mathematical notation developed for students who are blind, was not used because of its complexity. Neither Edward, the teacher nor the tutor knew it, and it was felt that learning it would be as difficult and complex as learning Braille. Therefore it was decided that learning it would be impractical.

Difficulties

Cognitive, affective, and psychomotor difficulties encountered were sometimes similar to those experienced by beginning statistics students and exacerbated by Edward's disability and sometimes were unique.

1) Low math self-efficacy. Edward's determination and perseverance were admirable, but it was clear that this course presented a greater challenge to him than to most students in the class. It had been several semesters since Edward's last math class, college algebra. Although he was committed to passing the statistics class, his remarks at the beginning of the semester showed a limited faith in his ability to make a B or an A; his initial goal was simply to complete the course with a passing grade. His confidence was shaken when he earned grades of F and D on the first two tests. It was further weakened when he learned that most of the members of his study group, who were sighted students, had similar grades and were dropping the course.

Refusing to drop the course, Edward rallied and earned an A on the final test and a B for the course grade.

2) Ethical dilemmas. Although the teacher gave "open-book" tests and expected students to use their books and notes, there were two issues unique to Edward's situation. The first issue concerned the role of the tutor during the test. Edward's initial belief was that the tutor was the same as a book or notebook and therefore should provide all information requested, including which formula to use. The tutor's position was that she would look up information in the book as requested, but not state procedures to be used. For example, she would not tell him which formula to use, but would read the formulas aloud. The second issue was whether and how to use copies of tests given to Edward by his friends. Tests from previous semesters were readily available and could be used to prepare for the tests. Edward and the tutor used these tests, as would any student, in practicing problems. Because the tests had similar problems, the activity proved helpful. Edward wisely chose to study all the problems even though the members of his study group did not. Hoping that the test would be identical, they studied only the problems on previous tests and failed; while Edward made a D. At the end of the semester, a friend gave Edward a copy of the final test and of her answers. Although Edward brought the test with him to the final exam, he chose not to use it, citing his faith in his own ability.

3) Conceptual frameworks. A significant part of the tutoring sessions was the communication of the concepts being taught rather than the computations. The role of the tutor was always to provide a concept map. A sighted student might, at the beginning of the semester, flip through the text or read the table of contents to see what statistics is about. For Edward, whose text was on tape, this was impossible. Therefore another important role for the tutor was translating advanced organizers from a visual to an auditory form. Previews of coming topics, overviews and reviews are crucial to orienting the student, organizing the material for storage, and retrieving the right information for the test. One way this was accomplished was by reading organizational charts in the text or creating flow charts. In Edward's text, a chart at the beginning of each chapter showed the material to be covered and indicated the relationships of the those topics to each other. Another way that conceptual organization was communicated to

Edward was through the tutor's verbal communication during sessions. Frequent "orientations" were given to indicate whether new topics were coordinate, superordinate or subordinate concepts to previous material. Verbal reminders were used during preview and review of materials. Transition sentences were used during homework problems and practice test sessions. Tactile aids, such as cutouts representing skewness, were provided as physical reminders whenever the concepts were discussed.

4) Computational sequences. The most pervasive difficulty was learning and following the steps in complex problems. These computational sequences were longer than Edward had encountered in any other math class; the order of operations was also more critical to obtaining the correct answer. Sighted students learn computational sequences by referring back to the sample in the book or in their notes. They can scan the page to check the computational sequence frequently. Edward learned the sequences by repeating the sequence or the formula aloud. The tutor frequently had provide verbal "markers" to facilitate this process at the beginning of the process; Edward's metacognitive strategies improved with practice. At the end of the semester, Edward knew that for every new problem type, he would have to learn the sequence and he learned to ask for confirming information from the tutor when he became confused about what to do next. The re-reading of the sequence for four or five-step problems was crucial because it took the place of what he would have seen in the book.

5) Experiential gaps. During the semester, a number of educational and experiential gaps were identified which hampered Edward's ability to solve statistical problems. Although he had studied math and completed the prerequisites of this course, there were a few very essential concepts which he had never learned. These missing concepts were usually easily acquired once they were identified. Examples of missing mathematical knowledge never learned were pie graphs and exponents greater than two. Missing mathematical skills which were difficult to acquire were using logarithms and extracting cube roots. Because Edward was honest about which parts of the course material he didn't understand, these situations could easily be addressed in the process of learning the material in the chapter. Tutors and teachers should realize, however, that their assumption that key concepts and skills are in place may be faulty.

They must be prepared to teach or re-teach the underlying skills and concepts in addition to the new material to be mastered.

A more difficult gap, an experiential gap, is one which cannot be taught while teaching the course material because it occurs as a result of a physiological deficit or experiential gap. An example of a difficulty with a physiological basis is Edward's inability to see color; therefore any references to "blue" or "red" in the text or problems were meaningless. Although Edward has heard these words his entire life, they carry no connotation other than "a quality or characteristic of an object which sighted people think is important". So a problem on permutations on packaging three different products together based on color is more difficult for him; he cannot visualize the solution in his mind. The same problem based on another characteristic, size, would have been more manageable.

Another kind of experiential gap is created when educators refer to activities in which people who are blind typically do not participate. Edward's previous educational or life experiences obviously were not those of a typical college sophomore. For example, he worked on cars, went swimming and enjoyed popular music; he didn't go to movies or listen to television. These differences generally didn't affect his academic work, but it was impossible to predict how his past experiences would impact the study of statistics. For example, Edward's reaction to a problem about a deck of cards was complete bewilderment. A particularly important problem on one of the tests required Edward to do a probability calculation about choosing cards from a deck. This probability topic had been taught and practiced previously using business examples and yet the problem that appeared on the test involved the likelihood of choosing a face card or the four of any suit without replacement. Edward admitted that he had never played cards and therefore, had no idea how to answer the question. The experiential knowledge that was required and which was not explicitly stated in the problem included knowing the number of cards in a deck, the number of suits, the number of cards per suit, and the number of face cards. To make the test question "fair", that is to make the experience of equivalent difficulty, the tutor gave him those numbers; he then easily calculated the probability. What would have been a "giveaway" question for sighted students, requiring merely recall and a simple use of the formula,

was a difficult and lengthy question for Edward. The amount of explanation, time and effort required to answer the question was not commensurate to the ten points awarded. This kind of question is especially difficult and anxiety-producing when they are unexpectedly part of examination and undoubtedly impacted his performance on the remaining items.

6) Practical issues. Two physical difficulties impacted Edward's performance in tutoring sessions and ultimately his final course grade. The first difficulty was the effect of physical and mental fatigue on his ability to do mental arithmetic. The impact of not sleeping due to noise in his dormitory was readily apparent the next afternoon in the tutoring session. Feeling ill also dramatically affected his concentration. Although these events would affect any student's performance, they seemed especially damaging to Edward's progress in the class. When they occurred, his ability to focus was impaired and therefore his ability to retain numbers in his short term memory and to perform operations on them was limited. On such occasions the sessions were usually shortened, the problems had to be brief, and the accuracy checks frequent. This fatigue was also debilitating when it was caused by many hours of mental arithmetic performed in other classes. Long hours of homework, studying, testing, and tutoring for other classes often decreased Edward's ability to profit from statistics tutoring. The second difficulty was Edward's sensitivity to his environment. Both ambient temperature and background noise were especially bothersome to him. Locations for tutoring couldn't be too hot or cold; a quiet room and, preferably, a quiet hallway, were needed. During testing, however, these physical conditions were rarely considered as the room was designated by the teacher or the departmental secretary. A cold room or a room near noisy faculty offices markedly changed Edward's ability to concentrate. What seemed to others "a reasonable level of noise" could make it impossible for Edward to hold a sequence of operations in his mind. It seemed to distract him as much as a flashing light might distract a sighted person during an exam.

7) Symbolic notation. Preparing formulae for Edward to read in Braille was impossible because for many mathematical symbols there is no Braille equivalent. The letters of the Greek alphabet proved particularly difficult to "translate" as Edward had never even seen the English written alphabet. The letters were therefore taught as arbitrarily selected and stand-alone

symbols. Sigma, for example, had to be taught so that he could understand the text and lecture. It was not necessary though to teach him that "sigma" is like an "s" nor was it necessary to make a raised symbol for him to feel. Because the word "sigma" had no accompanying visual or tactile referent, an explanation was always given when using it (e.g. "sigma or summation").

Although the causes of these difficulties were never discussed openly with Edward, all seemed to be a complex interplay of Edward's physical and psychological make-up and his previous educational and social experiences. All of these difficulties were addressed to a lesser or greater degree in the tutoring sessions, and some improved but none were resolved.

Instructional Strategies

Some instructional strategies which were successful in overcoming Edward's cognitive difficulties may also be useful for sighted students. These strategies included teaching to Edward's strengths, tactile/kinesthetic and auditory processing. One example of each of these strategies is given below.

1) Kinesthetic explanations. Whenever possible, concepts were explained through body movements. For example, the standard deviation was explained by stretching his fingers to the width of a standard deviation for a sample problem. Using graphs of several data sets, the varying width of the standard deviation could be demonstrated. He could feel the distance between the lines of a graph. The concept of the standard deviation as a descriptor for the "spread" of the scores was easily understood as his fingers "spread".

2) Cardboard curves. A normal curve approximately twelve by eight inches was cut from cardboard and glued to a slightly larger cardboard rectangle. The curve, which was then slightly raised from the background, was used in all problems involving Z-scores. An indentation was made by scoring the cardboard at the 50th percentile. Braille labels were glued beneath the curve to mark the location of each standard deviation. Two large rubber bands were stretched over the rectangle and used to represent the upper and lower limits of the area being considered in the problem. Feeling the rubber bands on this curve served the same function for Edward as drawing and shading the portion of the curve would for a sighted student.

3) Very small data sets. Although Edward's long-term auditory memory was very impressive and his short-term auditory memory was larger than that of most students, it was time-consuming, cumbersome and mentally taxing to use the large data sets in the book's sample problems. Edward could easily, however, operate on seven numbers and performed mental arithmetic faster than some students with paper and pencil. When teaching a skill which required recognizing patterns, it was easier to generate a small data set than use the sample problems in the text. An example is in finding the mode. If the book had a data set of twenty, it wasn't necessary for Edward to listen to all twenty numbers to learn the definition of mode. Seven numbers were sufficient for teaching and a slightly larger set of numbers could be used for practice. As the problems increased in complexity, generating data was no longer easy or quick. Then the problem-solving could be taught by picking out a sample of seven numbers from the larger data set given in the book. It was sometimes difficult to choose a subset which was representative of the set, but the time saved was enormous. The procedure for calculating the mean, for example, is the same regardless of whether seven or twenty numbers are used.

4) One memorable problem. Edward needed a cue for each formula or procedure taught. A single example worked better than many, and examples which were personally interesting, of course, were most effective. Although most of the text's sample problems concerned management decisions based on data, Edward preferred a single example about a subject relevant to college students: grade distributions, money spent on entertainment by students, textbook costs. During tests, he could cite these example problem more quickly than the formula and use them as a cue for remembering the formula and the procedure to be used.

Recommendations

Teachers and tutors of students who are visually impaired face the doubly daunting challenge of "translating" statistics, especially its graphic presentations, into auditory and tactile/kinesthetic messages, and tailoring that message to the individual student. Even if a teacher or tutor chooses to ignore the very relevant affective aspects of teaching, the cognitive aspects are most effectively addressed by re-examining the most fundamental instructional issues.

1) Theoretical basis. Information processing theory should be used as a basis for instruction because it most closely describes the parts of the teaching/learning interaction which must be changed. The input, storage and retrieval of information will be different for students with visual impairments. Difficulties in learning can be reduced or eliminated by examining and changing how the student receives, processes, remembers and recalls the information being taught. The most crucial part of the learning process for Edward was input. Awareness of and care with communication was paramount. Auditory input was less effective if it was filled with visual analogies or references to visual events. Communication which relied on the tactile/kinesthetic mode was sometimes offensive if it seemed too "elementary". The storage part of the learning process could be facilitated through cues or "hooks" provided by the tutor but required repetition. In Edward's learning, the repetition was most effective when very similar or identical messages were sent. Giving ten different examples of a process didn't seem to make it easier for him to store the process correctly. During the semester, Edward changed how he filed the information presented; sometimes he could refer to the chapter in which it appeared and sometimes to the example problem. The most effective way to facilitate the retrieval of information seemed to be frequent and periodic reviews of the material. A daily review at the beginning of each session served both as retrieval practice and an ongoing technique for formative assessment.

Using the information processing theory as a basis for instruction is also important because of the need for students with impairments to be aware of how they learn and which alternative strategies are most effective. Metacognitive strategies were generated spontaneously by Edward over time. The most effective of these involved a dialogue with the tutor, usually a variation of "talking through the problem". These conversations evolved into a version of self-talk. "Name the variables we're given. Which one do we need to find? What kind of problem is this? Which one is it like? Which formula do we need to use? What do we need to do? What does that number (the answer) mean? Now what do we write?"

2) Type and severity of visual disability. It seems self-evident that teaching a student like Edward requires different degrees and types of instructional changes based on the student's visual impairment. A student blind from birth, such as Edward, reacts differently to a lesson than a student whose sight was recently damaged who has a memory of sight. Students with impairments such as color blindness or night blindness involve require different accommodations than students with limited residual vision after an illness. Asking the student about lighting conditions, print size requirements, the use of Braille and Nemeth Code, and other accommodations is very important.

3) Individualized teaching. Teachers and tutors must rely on the self-awareness of the student, the student's knowledge of his or her own strengths and weaknesses, the student's choice of effective learning and coping strategies, and the student's already-developed compensation skills and strategies. Edward refused some of the commonly suggested accommodations for students with visual impairments such as handouts and tests in Braille because he preferred learning by listening to tapes and oral test-taking. He preferred to use the strategies that he had developed in the past. At the beginning of the semester, experimentation was intense as Edward tried to adjust what he knew about himself to the requirements of this new area of study. Tutoring sessions seemed to be continuing attempts to find the best interactions but on a trial-and-error basis. The tutor needed to ask, at first, for reactions, and to adjust constantly to Edward's needs and preferences. As the semester progressed, Edward developed new strategies and became more confident in his ability to direct the tutoring sessions. His judgment also seemed to improve concerning the most effective use of his study time. By the last three weeks of the semester he could confidently decide how much new material to cover, how many problems were necessary for mastery, and what topics to review. The tutor, however, needed to continue to monitor his reactions and adjust lessons as his abilities and preferences changed.

4) Continuous formative assessments and adjustments. Throughout the semester, but particularly before the first test, formative assessments were necessary to adjust the variables of instruction such as speed of delivery, length and complexity of explanations, and type of

examples. Therefore time was allotted during each hour session to check Edward's declarative, procedural and strategic knowledge. These assessment techniques were casual, conversational and without pressure. Sometimes the technique was as simple as asking specifically for questions he might have about the reading or lecture. Another technique was asking for recall of both conceptual and computational information by reviewing a simple problem from the previous session. Most effective, however, was asking Edward to paraphrase in his own words the key ideas most recently learned. As the main concepts of the chapter became clearer, this formative assessment became a review of specific procedures or formulae. During these later sessions, the review was generally initiated by Edward and consisted of reviewing problems. As he mastered each type of problem, the review consisted of telling how to do the problem rather than working it completely. These casual conversations also served effectively to address the affective issues which impacted his performance. As the semester progressed, these conversations took on a more self-directed thrust as Edward monitored and shared practical difficulties . The pressures of other courses impacted his progress; his study group no longer seemed productive. He chose to stop attending class as did others in his section and to use that time listening to the text cassettes and review tapes.

Conclusion

Edward's success in his first statistics course dramatically improved his self-efficacy regarding mathematics. He had successfully completed what would be a difficult course for any undergraduate. Despite his disability, a course load heavy in mathematics, and frustrating classroom experience, he met the course requirements for his major and now faces the challenge of the second course in the statistics series, a quantitative methods course which covers topics from correlation to regression.

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