HOW WE TEACH | Generalizable Education Research

An IDeA for enhancing undergraduate research at rural primarily undergraduate institutions

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Sens DA, Cisek KL, Conway P, Doze VA. An IDeA for enhancing undergraduate research at rural primarily undergraduate institutions. Adv Physiol Educ 41: 464–471, 2017; doi:10.1152/advan.00041.2017.—This study documents the efforts of the North Dakota (ND) IDeA Networks of Biomedical Research Excellence (INBRE) program to assist in the development of undergraduate research programs at four state-supported primarily undergraduate institutions (PUIs) in ND. The study was initiated in the 2004–2005 academic year and continues to the present. The study shows that gaining initial institutional support for undergraduate research was assisted by providing salary support for faculty involved in undergraduate research. Once research was ongoing, each institution evolved its own unique plan for the use of support from the ND INBRE. Undergraduate student researchers have prepared, presented, and defended their research results on 188 unique posters since initiation of the program, with many posters being presented at more than one meeting. PUI faculty have authored 35 peer-reviewed manuscripts. Evaluation has shown that over 95% of the undergraduate students performing research matriculated with their bachelor’s degree. Career choices of 77.2% of these graduates was determined, and 37% pursued a career in the health professions. Of the students not pursuing a post-baccalaureate degree, 81.2% chose careers directly linked to science. The study reinforces the concept that undergraduate research can be performed directly on the PUI campus and be of value in preparing the next generation of health professionals in research, service, and teaching.

career outcomes; first generation; frontier counties; primarily undergraduate institution; undergraduate research

THE STATE OF NORTH DAKOTA (ND) participates in the Institutional Development Award (IDeA) Networks of Biomedical Research Excellence (INBRE) program supported through the Center for Research Capacity Building within the National Institute of General Medical Sciences of the National Institutes of Health (NIH) (7). The INBRE program is one arm of the Center for Research Capacity Building’s IDeA program, which is designed to foster health-related research and enhance the competitiveness of investigators at institutions located in states in which the aggregate success rate for applications to NIH has historically been low. These states with historically low success rates currently number 23 plus Puerto Rico. A central goal of the INBRE program is to promote the development, coordination, and sharing of research resources and expertise that will expand the research opportunities and increase the number of competitive investigators in the IDeA-eligible states. Each state that participates in the INBRE program is expected to establish a multidisciplinary research network with a scientific focus that will build and strengthen the lead and partner institutions’ biomedical research expertise and infrastructure; build and increase the research base and capacity by providing research support to faculty, postdoctoral fellows, and graduate students at the participating institutions; provide research opportunities for undergraduate students and serve as a “pipeline” for undergraduate students to continue in health research careers within IDeA states; provide outreach activities to students at undergraduate institutions, community colleges, and tribal colleges participating in the state’s network; and enhance the science and technology knowledge of the state’s workforce. Individual state grantees are given ample leeway to develop strategies to achieve these expected goals.

One strategy employed by the ND INBRE to achieve a subset of the above goals was to develop a research culture at the state’s four primarily undergraduate institutions (PUIs). These institutions, named after the communities in which they are located, are Dickinson State University (DSU), Mayville State University (MaSU), Minot State University (MiSU), and Valley City State University (VCSU). ND is a rural agricultural and energy-producing state with a very large land mass and an extremely small population. The current population of ND is 757,952 individuals (11), who occupy a land mass of 68,976 square miles, or an occupancy rate of <10 citizens/square mile, compared with a national average of 80 citizens/square mile. The rural nature and low population of ND are reflected in the enrollments at the PUIs, which are as follows: DSU (1,386), MaSU (1,130), MiSU (3,412), and VCSU (1,452) (13). In addition, 36 of 53 counties in ND retain a federal designation as “Frontier Counties,” as they have a population of less than six individuals per square mile (9). This fact alone defines that a significant population of students in ND experience a disparity in the level of educational opportunities available at the K–12 levels of education, especially those opportunities advancing a career in science, technology, engineering, and math (STEM). Further limiting educational access to the undergraduate citizens of ND is that there are only two interstate highways: one in a north-south direction along the border of Minnesota, and the other in an east-west direction across the lower one-third of ND. In addition, ND is known for

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METHODS

Data acquisition: undergraduate students. The acquisition of data pertaining to student participation in the ND INBRE program at the PUIs comes from a number of sources. One source is from the project directors at the PUIs. They provide basic information on student participants, such as name, school location, laboratory director and research area, attendance years, and approximate amount of participation. Graduation data for students’ matriculation to the bachelor’s or other degree(s) are collected from the National Student Clearinghouse, registrars’ offices, news releases, and graduation programs publically provided by the respective universities. Career paths of students following graduation from the PUIs are also collected from a variety of sources. A major resource for student career tracking is social media, as many students maintain contact with faculty and program staff through a variety of social media platforms. In addition, many students maintain social media platforms that can be routinely accessed by program staff. This resource has been especially prevalent in the later years of the program. The ND INBRE program sponsors an annual undergraduate research symposium, where the project directors and student researchers present posters of their research. At the symposium, ND INBRE requests, but does not require, that each student participate in a survey that collects basic information, such as name, school location, laboratory director and research area, and future contact information. The ND INBRE program also tracks student outcomes via a short survey with checkbox questions and the ability for the students to provide written feedback. The ND INBRE does not collect social security numbers. All information is stored in a database on a secure server maintained by Information Technology Services at the University of North Dakota School of Medicine and Health Sciences. All activities related to the gathering of information for undergraduate student participants in the ND INBRE program are approved by the Institutional Review Board of the University of North Dakota.

Data acquisition: faculty participants. The scholarly products produced by the PUI participants in the ND INBRE program are collected each academic year from the project directors at each participating PUI. The scholarly products consist mainly of poster presentations, oral presentations, professional proceedings, and peer-reviewed publications. Only publications acknowledging NIH IDeA program support are counted as a scholarly peer-reviewed publication product of the ND INBRE program. The number of faculty that currently participate in the program by 10.220.33.1 on August 29, 2017 http://advan.physiology.org/ Downloaded from

RESULTS

Undergraduate student participation. The support in the initial years to the PUIs from the ND INBRE program was constructed to provide a financial buy-out of faculty effort at ~50% during the academic year and for 1 or 2 mo of summer salary support. The support also provided for student employment at $10/h, laboratory supplies, travel, and publication and presentation costs. This support was initiated late in the 2004–2005 academic year. The ND INBRE administrative core surveyed the PUIs for their level of student research before the initiation of the ND INBRE program and found only very limited levels of undergraduate student participation in research. The low participation of undergraduates in research was also confirmed by searching for scholarly products from the PUI institutions. This search also showed a low level of undergraduate student research, which, when present, was mainly oral presentations at the North Dakota Academy of Science annual meetings. For an undergraduate to be identified as a participant in research required a minimum of one semester of participation at an approximate minimum of 10 h of participation each week. The majority of students, estimated at over 75% of the student participants by the project directors, exceed this minimal level of participation. The effect of ND INBRE support on student participation in undergraduate research is shown in aggregate for all of the PUIs (Fig. 1) and for each individual PUI (Fig. 2) from 2004 to the present. These results show that undergraduate student research participation increased at each PUI shortly after initiation of ND INBRE support. The results also show that, once support was initiated, the number of undergraduate student researchers stabilized at each of the participating PUI institutions. This probably reflects the fact that ND INBRE financial support was similar in each succeeding year following program initiation, as was the student enrollments at the respective PUIs. MiSU had the greatest number of undergraduate researchers and presentations of posters, in line with their larger student enrollment. The number of faculty that currently participate in the program also follows student enrollment, with MiSU having eight, DSU...
and MaSU three each, and VCU with two faculty participants. The administrative core meets with the project directors several times each year. In these meetings, the project directors did not indicate that an increase in funding would increase the number of students performing research; however, they did indicate that increased funding would result in more hours worked per student. Meetings with the project directors and the Vice Presidents of Academic Affairs (members of the internal advisory committee) at the PUIs, indicate that ND INBRE has fully engaged the faculty and students interested in INBRE-supported biomedical-related undergraduate research. An interesting trend, partially discernable in the participant numbers from 2010 onward, is that the PUI project directors, with agreement by the ND INBRE, did raise student compensation to between $12 and $15 per hour due to employment pressure for student workers resulting from the oil boom that occurred in the western region of ND. MiSU and DSU were impacted the most by the oil boom, with respect to the retention of undergraduate students, since they serve the western regions of ND.

Undergraduate posters and faculty peer-reviewed publications as PUI scholarly products. The students and faculty who participate in the ND INBRE program are expected to present posters of their accomplishments on a yearly basis. The number of posters presented by students is determined using a defined set of criteria. A poster is counted only one time, even when presented at multiple meetings. The poster is also counted only once per title and presentation, even when multiple undergraduate authors are present on a given poster. Posters with only PUI faculty as authors are not counted as products for this report. The administrative core of the ND INBRE could not get an accurate account of undergraduate posters and presentations before the 2005–2006 academic year; thus results are presented from 2006 to the present. There were 334 unique poster presentations by undergraduate students over the period of 2006 to the present. The breakdown in poster presentations per year by the four PUI ND INBRE partners shows a trend for an increase in the number of posters as ND INBRE support was established over time at the PUIs (Fig. 3). The relatively large number of posters in 2006 resulted from...
undergraduate research from the current year, as well as several past academic years, with presentation being motivated due to the enthusiasm of the newly acquired ND INBRE support. The numbers of undergraduates presenting posters closely follows the student enrollments of the four PUIs, with MiSU producing 188 posters, MaSU 58, VCSU 58, and DSU 30. Pointedly, DSU is the PUI most affected by the significant increase in ND oil production since the initiation of the ND INBRE.

In October of 2009, the ND INBRE program established the ND INBRE Undergraduate Research Symposium to stimulate interaction among faculty and students of the network partners and to provide a forum for undergraduates to present their research results via poster presentations. The symposium is held in Grand Forks, ND, and is a full-day event, with most participants arriving the night before the symposium is to begin. The morning is dedicated to oral presentations, and the afternoon to a poster session and opportunities for networking. The administrative core of the ND INBRE program provides housing and food for all attendees, while the PUI project directors arrange travel to and from the symposium. The ND INBRE administrative core encourages students to stay over the night the symposium ends due to the long travel distances of some of the PUI partners (e.g., Dickinson to Grand Forks, ND, is 350 mi.). The symposium has been held yearly since 2009. As shown in Fig. 3, there is a notable trend for an increase in the number of posters authored by undergraduate researchers following the establishment of the symposium. An additional impact of the symposium is a stimulation in the number of meetings at which the poster will be presented by the undergraduate author. Before the ND INBRE symposium, only two posters were presented at more than one meeting. After establishment of the ND INBRE symposium ~18% of the posters each year are presented at one additional meeting, with several each year being presented at three or more meeting sites.

The PUI faculty supported by the ND INBRE have published 35 peer-reviewed papers that cite IDeA support since initiation of the program in 2006. Several of the early publications, although fully or partially supported by ND INBRE, did not acknowledge funding from the IDeA program of the NIH. The recognition of the need to acknowledge program support was an important part of the development of the research culture at the PUIs.

Research topics, promotion and tenure, facility and administration costs, and research administration. There are at least two research programs available to the students at each of the PUIs (Table 1). The ND INBRE administrative core has also monitored the pathway to promotion and tenure of all of the faculty project directors of the ND INBRE. The eight project directors associated with the ND INBRE, beginning in 2006, have all received tenure on time (6 yr post-assistant professor appointment), and all have achieved the rank of professor. Faculty who became associated with the ND INBRE program in later years are mixed in rank and tenure, from recently hired individuals on a tenure track, to full professors with tenure who have recently joined the program. To date, no project director of the ND INBRE has been denied tenure when eligible. That participation in the ND INBRE had a positive influence, but not the only influence, on the award of tenure, was indicated through conversations with Vice Presidents of Academic Affairs at each of the PUIs. The ND INBRE administrative core has also monitored the development of research infrastructure at each PUI. At the beginning of the program, the PUIs did not have an individual dedicated to grants management, and most had the NIH default rate for indirect costs. At present, each PUI has an individual dedicated to grants management, and all PUIs have renegotiated their facility and administration rates at least once since initiation of the program.

Table 1. Undergraduate research topics

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<th>Dickinson State University</th>
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<td>The Role of c-Met in Acidic Extracellular pH-induced Cell Motility and Invasion</td>
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<td>Maysville State University</td>
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<td>Minot State University</td>
<td>Ghrelin Interaction with Genetic Risk Factors of Methamphetamine Addiction</td>
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<td>The Role of Allosteric Disulfide Bonds in Cellular Infection and Metal Insertion</td>
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<td>Caffeine: A Model Drug for Studying Environmental Factors in Addiction</td>
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<td>Valley City State University</td>
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<td>Environmental Health: Coal Fly Ash Phytoremediation and Plants</td>
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Student views of the impact of the ND INBRE research experience. The impact the ND INBRE research experience had on students following completion of the program was assessed by a brief seven-question survey based on a 1–5 scale, with 1 being “not at all” and 5 being “a great deal.” In addition, the survey had an open comment section, so students could give additional input regarding the impact/satisfaction of the program. The survey assessed students who completed the program from 2008 to the present. These follow-up surveys were conducted in 2012 and 2016 and did not include the re-survey of students captured in 2012. A total of 124 responses were received from students who had completed the program, and these were divided equally between the two survey periods. The questions and the numerical results of the survey are presented in Table 2. The overall student response to the survey was that the research experience provided by the ND INBRE was valued by the students. The two lowest scoring questions, “Influenced my career decision” and “Improved my chances for admission in post graduate programs,” had several evaluations of 1’s and 2’s that were accompanied by written comments indicating that these students knew exactly what career they wanted before entering the research laboratory. The question, “Increased confidence in my ability to do science,” scored highly and was accompanied by many written comments reinforcing the positive impact of undergraduate research on the student’s increased confidence to perform research. This comment approached ~50% of the comments provided by the students. There was also no difference in the student’s view of the impact of the program between the surveys performed in 2012 and 2016. Student demographics. The graduation rates of the students participating in research was over 95% at each PUI. Data were not collected on the number of years each student needed for graduation. The project directors estimated that the majority of students performed research after their second year of college, and that participation by first- and second-year students was rare. Female students comprised 57.2% of the students in the program, and this was similar at each PUI. More than one-third (38%) of the students were the first generation to attend college. Of those students reporting (170), 82.4% were white, 10% American Indian/Alaskan native, 7.6% African American, and 0% Hispanic or Latino. The student demographics were similar to the overall demographics of ND, which are as follows: White, 87.9%; Black or African American, 2.9%; Native American or Alaskan Native, 5.5%; Asian, 1.5%; Native Hawaiian or Other Pacific Islander, 0.1%; two or more races, 2.1%; Hispanic or Latino, 3.6%; White, not Hispanic or Latino, 85.0% (11).

Student careers following graduation. The careers of the students completing the bachelor’s degree at the four PUIs has been followed by the administrative core of the ND INBRE. The administrative core was able to identify the postbaccalaureate status of 236 students (77.2%) who graduated from the four PUI institutions. The ND INBRE administrative core was also able to determine the job or educational status of the identified students. These were segregated into two categories. One category was for students who pursued postbaccalaureate degree programs in the health professions (Table 3), and the other was for students completing the bachelor’s degree with subsequent entry into the workforce (Table 4). The postbaccalaureate results (Table 3) include both students who completed a degree program, as well as those currently enrolled in an advanced degree program. In addition to terminal degrees (Doctor of Medicine, Doctor of Philosophy, Doctor of Pharmacy, Doctor of Dental Surgery, Doctor of Veterinary Medicine), the category for health professions included the following: occupational therapy, physical therapy, clinical laboratory science, physician assistants, nurse, optometry, podiatry, and chiropractor. The categories of jobs for individuals completing the bachelor’s degree and entering the job market are general in definition (Table 4). Technician is very general in job definition, since some graduates reported simply that they were employed as technicians, and others were more specific to the type of laboratory or business. This was also true for the category of chemist/environment, where some individuals were very specific, and some simply reported being a chemist.
or working in some way connected to the environment. The remaining categories were more straight-forward regarding type of job reported by the graduates.

**DISCUSSION**

There is wide acceptance that undergraduate research is a valuable addition to the undergraduate educational experience. As summarized by Madan and Teitge (4), in their students’ view, the value of undergraduate research is accepted in many fields of study. These empirical observations regarding the value of undergraduate research have been discussed at length in engineering (6), medicine (5), biology (8), physiology (2), neuroscience (3), psychology (12), as well as in multidisciplinary discussions in journals with high impact factors (1, 10). However, the fact remains that most studies are based on empirical observations because a valid control group is difficult to identify. The present study extends this trend and presents empirical observations and outcomes in establishing a research culture at PUIs in a rural state.

When the ND INBRE program was initiated, there was only nascent undergraduate research at the four state-supported PUIs in ND. An advantage of the ND INBRE program was the availability of resources that allowed at least one faculty member at each institution to receive salary support, in line with releasing 50% of that individuals’ teaching effort during the academic year to do research. The ability to offset salary was of major importance in gaining the PUI acceptence of an increased focus on undergraduate research. Salary offset alleviated initial administrative concerns at each institution that teaching would suffer at the hands of an increasing interest in research. This concern was minimized over time and further lessened by student and faculty enthusiasm for undergraduate research. An important observation is that each school evolved independently over time and adapted research support from the ND INBRE to fit the culture of their individual university. This is illustrated by the current use of ND INBRE support at each PUI. One PUI has continued to focus a major portion of ND INBRE support to a full research project with substantial faculty salary support and a minor pilot project for a junior investigator. A different PUI has taken the support from the ND INBRE and divided the resource equally as pilot projects for three interested faculty members. Another PUI has taken the support from the ND INBRE and divided the support to continue two long-standing research projects and seed fund a third project for a junior faculty member. The final PUI took all available ND INBRE resources and reached an agreement among eight interested faculty on the level of support each needed to participate at their desired level in undergraduate research. In all cases, institutions and investigators had to demonstrate that the research projects maximized undergraduate participation, were statistically sound, and had all necessary institutional approvals. An important observation remains that, in early stages of the development of undergraduate research, it was important to ensure that it improved the educational experience and was not detrimental to course instruction.

The findings on student outcomes are very supportive of the value of undergraduate research. The number of students who matriculated with the bachelor’s degree was very high, exceeding 95% for those participating in undergraduate research. This is in contrast to the known completion rates of the PUIs that are between 34.1 and 48.0%. Unfortunately, the evaluation program did not capture the on-time graduation rate of the undergraduate students who participated in the ND INBRE. The high rate of completion of the bachelor’s degree by the student researchers may, however, simply reflect that students who elect to pursue research are already highly motivated to complete the degree process. Regardless, the undergraduate research experience can be viewed as a positive in career completion and one that definitely did no harm. Another positive indication of the value of undergraduate research on degree completion is that ~38% of the students were from families in which no member had previously received a bachelor’s degree. Furthermore, 17.6% of the students were from groups underrepresented in STEM majors (10% American Indian; 7.6% African American). Both first-generation and underrepresented minorities, particularly Native Americans, are recognized as being of high risk for degree noncompletion. The ND INBRE was also able to determine the career choices of ~77.2% of the students who completed the program. Of these students, 37% pursued a postbaccalaureate degree in the health professions. Of the students not pursuing a postbaccalaureate degree, 81% chose careers directly linked to science. The remainder found careers in the general area of management, the armed forces, or law enforcement. The results are empirical, as the authors could not identify comparative data from other rural PUIs for comparison. Regardless, the high level of student success is supportive of the concept that undergraduate research is a value-added component that will help prime the pipeline for the next generation of health professionals in research, service, and teaching.

Another important aspect of the ND INBRE program was the establishment of a venue for effective networking among all of the participants of the program. The ND INBRE established a yearly ND INBRE Undergraduate Research Symposium for all students who might be supported by the ND INBRE or related programs. This included the PUI program, as well as students from the research-intensive universities and tribal colleges. A central feature of the symposium is an afternoon poster session, where undergraduate students presented their research to faculty, graduate students, postdoctoral fellows, and other undergraduate student researchers. The session was arranged so that one set of students present their posters for a given time period and then are released and free to visit posters presented by a different set of students in an alternate time period. Using this format, a student might present and defend his or her poster to as many as 45 individuals. As shown in the results, the symposium increased the number of undergraduate student presentations. It was also demonstrated that, once a student produced a poster, there was an increased likelihood that the poster would be presented at additional meeting(s). As noted by program evaluation, one of the most positive aspects of the ND INBRE program identified by the students was that it increased their confidence that they could perform research. The poster session appeared to have a large impact on student confidence. The timing of the symposium is problematic. The ND INBRE chose a date in October, since it gives graduating students an opportunity to explore job opportunities with companies, health professional schools, and graduate schools attending the symposium. The limitation is that students newly entering the research laboratories had only limited time to generate results. A spring meeting has the
undergraduate research necessary before an institution is ready for undergraduate research. A caveat of this approach was to provide ND INBRE funding for new investigators with inter-

experienced investigators to an alternate funding source and for funding consideration. This effort should begin to transition applicants will be required to submit their R15 proposal to NIH history of funding from NIH to assist investigators. Successful awards favored by research-intensive institutions. A major goal that remains for the ND INBRE program is to assist the participating institutions to achieve a sustainable undergraduate research program. This was viewed as being highly difficult, if not impossible, until a research culture emerged at each PUI. A major resource that will be targeted by the ND INBRE in the future is to encourage and assist investigators to submit applications for R15 grant support from the NIH. This program, formally called the NIH Academic Research Enhancement Award, is tailored to support biomedical and behavioral research at PUI institutions. To the authors’ knowledge, this is one of the few mechanisms available that provides salary support for faculty and students, an adequate supply budget for research, travel, and other expenses necessary to support undergraduate biomedical research. The ND INBRE views the R15 as a preferred funding mechanism for rural PUIs, since these institutions face significant hurdles in competing for the more lucrative and prestigious NIH R01 awards favored by research-intensive institutions. A major issue at the PUI institutions is productivity, as viewed by the acceptance and publication of peer-reviewed papers. The ND INBRE experience is that investigators employing primarily undergraduate students for research can produce on average one peer-reviewed paper every 3 yr. This is likely a rate of production below the level necessary to be competitive for R01 level funding. The ND INBRE plans to require future requests for funding from established ND INBRE investigators to employ the application format of the R15 award. The ND INBRE will provide peer review of proposals and mentors with a history of funding from NIH to assist investigators. Successful applicants will be required to submit their R15 proposal to NIH for funding consideration. This effort should begin to transition experienced investigators to an alternate funding source and provide ND INBRE funding for new investigators with interests in undergraduate research. A caveat of this approach was recognizing the substantial length of time and investment in undergraduate research necessary before an institution is ready to begin a transition to investigator-independent funding resources.

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DISCLAIMERS

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AUTHOR CONTRIBUTIONS

D.A.S., K.L.C., and V.A.D. conceived and designed research; D.A.S., K.L.C., P.C., and V.A.D. analyzed data; D.A.S., K.L.C., P.C., and V.A.D. interpreted results of experiments; D.A.S. and V.A.D. prepared figures; D.A.S. and V.A.D. drafted manuscript; D.A.S., K.L.C., and V.A.D. edited and revised manuscript; D.A.S., K.L.C., P.C., and V.A.D. approved final version of manuscript.

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