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Why domain-specific science knowledge matters in teacher certification: Focusing on evidence for effective science teaching.

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DEPARTMENT OF TEACHING,
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Why Domain-Specific Science Knowledge Matters in Teacher Certification

Focusing on Evidence for Effective Science Teaching

The landscape of teacher preparation is complex. From a research perspective, how to prepare teachers presents as a multilevel, multivariable puzzle. For decades, federal and state policymakers, educational researchers, and administrators, along with teacher education institutions, school districts, and other stakeholders have tried to determine and measure the key malleable factors that result in effective teaching (NRC, 2010).

Periodically, state departments of education review secondary science teaching endorsement policy guidelines. As revisions occur, teacher educators in higher education and district administrators need to engage in a multidisciplinary discussion about:

1. the ways in which **strong domain-specific science content knowledge contributes to better opportunities for students to learn science**,
2. why **robust secondary teacher certification standards are vital for** achieving not only K-12 scientific literacy, but also **better preparation** of career and college-ready students, and
3. the **problems caused by underprepared secondary science teachers** who have only minimal, introductory-level college science coursework via **general science endorsements.**

A recent study by Nixon, et al. (2017) showed that only about one-third of science teachers in their first five years are assigned to teach in-field. They also reported that about 20% of teaching assignments were entirely out-of-field and about 43% of assignments were some combination of in-field and out-of-field.

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Standard 1: Content Knowledge

The National Science Teachers Association's 2012 Teacher Preparation Standards state:

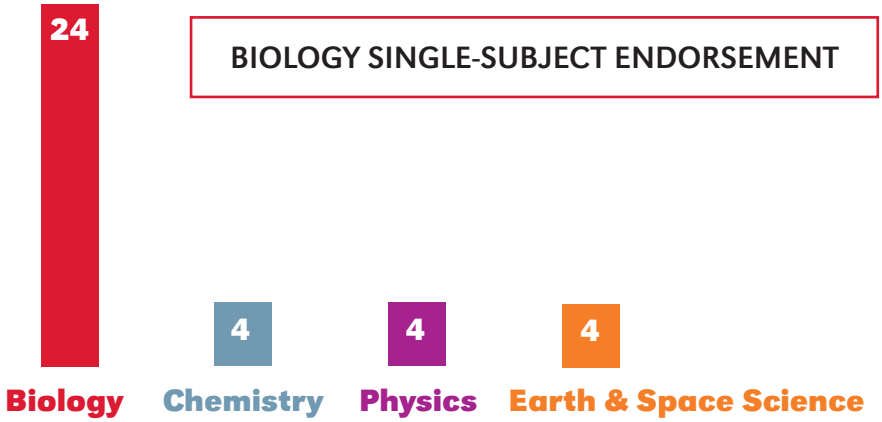
"Effective teachers of science understand and articulate the knowledge and practices of contemporary science. They interrelate and interpret important concepts, ideas, and applications in their fields of licensure."

Context of Teacher Preparation and State Certification

Nebraska Secondary (7-12) Science Teacher Certifications

In-Field Teaching with a Single-Subject Endorsement

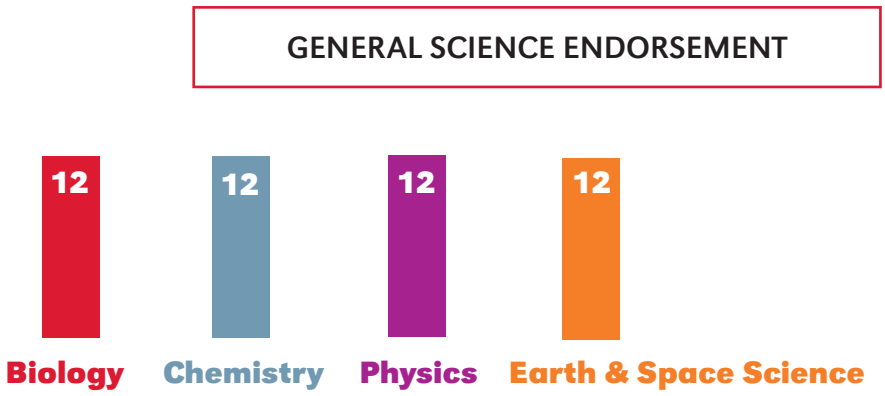
24 credit hours minimum in either Biology, Chemistry, Physics, or Earth and Space Science, plus 4 additional credit hours in each of the other three areas (36 credit hours total). See biology endorsement example.



Out-of-Field Teaching with a General Science (Broad Field) Endorsement

This certification allows science teachers to teach any area of science.

12 credit hours in each of the four areas: Biology, Chemistry, Physics, and Earth and Space Science (48 credit hours total)



Teachers with just a **General Science (Broad Field) Endorsement** only have 50% of the domain-specific content preparation that a single-subject endorsement provides, yet teachers are still permitted to teach any of these four subjects. One-half of all states in the U.S. have dismissed general science endorsements in favor of disciplinary-specific endorsements (NRC, 2010).

Discussion

When teachers teach out-of-field...

1. They lack confidence and subject matter knowledge that is necessary to teach using inquiry-based approaches (Treagust, 2014).
2. They are less likely to recognize student misconceptions and more likely to teach oversimplified content (Sadler & Sonnert, 2016; Hashweh, 1987).

State teacher certification policies can inadvertently support out-of-field teaching (e.g., providing a general science endorsement with minimal subject matter requirements). To improve student performance in the sciences, state science teacher endorsement policy should:

- **restrict a general science (broad field) endorsement to middle school teachers,** and
- **require robust single-subject endorsements of all high school science teachers.**

Frequently Asked Questions

#1: WHICH IS MORE IMPORTANT: SUBJECT MATTER KNOWLEDGE OR PEDAGOGICAL KNOWLEDGE?

Answer: Both sets of knowledge are important. Teacher preparation program designs should have strong subject matter knowledge requirements, high-quality education coursework, and effective mentorship. Science teachers with strong content knowledge not only know their subject matter better and have fewer misconceptions themselves, but are also better able to teach science in line with science education standards and learning outcomes (Treagust, 2014; Lewis, et al, 2018). Alternatively certified math and science teachers, without a strong pedagogical foundation, versus those teachers with more traditional preparation routes, are 25% more likely to leave schools and the teaching profession (Carver-Thomas & Darling-Hammond, 2017). Well-prepared, effective teachers provide students with a more rigorous science education and better prepare students for college and to seek scientific careers.

#2: CAN'T ANY SCIENCE TEACHER TEACH A SCIENCE COURSE?

Answer: No. While it is tempting to think that science teachers are interchangeable, the situation is not this simple; unfortunately, out-of-field teaching is more common than it should be (Nixon, et al, 2017). At what minimum point is a teacher "qualified," and which science (and what subject matter knowledge) does a teacher have? Science content knowledge is discipline-based, and for K-12 science education purposes, there are three main domains of science: life science, physical science (chemistry and physics), and Earth and space science. These three categories are also how state and national science education standards are organized and tested. Thus, teachers must be well prepared within a specific domain in order to be effective teachers who themselves don't hold misconceptions in that content area. Half of all states have done away with their general science endorsements (NRC, 2010), as a general science endorsement does not require that teachers go beyond lower-level college science courses. Without upper-level science courses, teachers do not sufficiently understand the nature of scientific inquiry with which to teach science (Hashweh, 1987) in line with state science standards.

#3: DON'T RURAL SCHOOLS WITH ONLY ONE SCIENCE TEACHER NEED TEACHERS WITH GENERAL KNOWLEDGE OF ALL SCIENCES?

Answer: No. First, no one teacher can know enough about all areas of science to be able to teach them at a high enough level, especially for high school students. Specifically, low-level exposure to science content is a poor substitute for a program of study that encourages teachers to gain deeper expertise in one area of science (e.g., life sciences). Once a teacher has an area of expertise in science with a strong conceptual framework of that science, then he or she can more easily add to their knowledge rather than viewing science as a disconnected series of facts. Second, most rural schools* in Nebraska, and states like it, typically have at least two science teachers who can divide teaching science between life science and physical sciences. There are a variety of ways Class 3 schools can handle the issue, but expertise is critical in those areas.

**92% of Nebraska schools (n=229) are categorized as Class 3.*

#4: ARE SCIENCE TEACHERS WHO HAVE A MASTER'S DEGREE TOO EXPENSIVE TO HIRE?

Answer: No. MA-certified teachers tend to cost less over the long term because they stay in the classroom. The average difference in pay for teachers who have obtained teacher certification through a BA versus a MA program is minimal (Table 1, data taken from NDE, 2018). Furthermore, more expensive or not, there is a shortage of highly qualified science teachers in most states, thus whether to hire them is a moot point. At UNL, 84%** of MA-certified science teachers with an undergraduate degree in science obtained jobs within one year of completing their certification as compared with 78% of BA-certified teachers. Also, replacing teachers who leave is expensive. It is estimated that it costs about $20,000 to replace one teacher who leaves an urban school district (Carver-Thomas & Darling-Hammond, 2017). Teachers who become certified through MA programs tend to stay in teaching longer (NRC, 2010), resulting in less staff turnover that negatively impacts hiring costs and student learning. At UNL, 91% of MA-certified teachers with an undergraduate degree in science who were hired stayed in teaching as compared with 80% of BA-certified teachers.

Table 1. Difference in pay for BA vs MS teachers

Area	Average Starting BA Salary	Average Starting MS Salary
Lincoln	$43,984	$46,069
Greater Lincoln	$36,040	$42,900
Omaha	$41,000	$45,100
Greater Omaha	$35,269	$40,683

*** UNL rates based upon seven cohorts of teachers (2012-2018).*

References

Carver-Thomas, D., & Darling-Hammond, L. (2017). *Teacher turnover: Why it matters and what we can do about it.* Palo Alto, CA: Learning Policy Institute.

Hashweh, M. Z. (1987). Effects of subject-matter knowledge in the teaching of biology and physics. *Teaching and Teacher Education, 3*(2), 109-120.

Lewis, E. B., Rivero, A., Musson, A., Lucas, L., Tankersley, A., & Helding, B. (2019). Educating Effective Science Teachers: Preparing and Following Teachers into the Field. In J. Carinci, S. Meyer, and C. Jackson (Eds.), *Linking Teacher Preparation Program Design and Implementation to Outcomes for Teachers and Students*. Charlotte, NC: Information Age Publishing.

Marshall, J. C., Horton, B., Smart, J, & Llewellyn, D. (2008). *EQUIP: Electronic Quality of Inquiry Protocol: Reviewed from Clemson University's Inquiry in Motion Institute*, www.clemson.edu/iim.

National Research Council (2010). *Preparing teachers: Building evidence for sound policy.* Committee on the Study of Teacher Preparation Programs in the United States, Center for Education. Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

National Science Teachers Association (2012). Science Teacher Preparation Standards.

Nebraska Department of Education (2018). Nebraska Teacher Salaries.

Nixon, R. S., Luft, J. A., & Ross, R. J. (2017). Prevalence and predictors of out-of-field teaching in the first five years. *Journal of Research in Science Teaching, 54*(9), 1197-1218.

Sadler, P., & Sonnert, G. (2016). Understanding misconceptions: Teaching and learning in middle school physical science. *American Educator, 40*(1):26–32.

Treagust, D. F., & Tsui, C. Y. (2014). General instructional methods and strategies. In N.G. Lederman & S.K. Abell (Eds.), *Handbook of Research on Science Education Volume II*, (pp. 303-320). New York, NY: Routledge.

Why Strong Subject Matter Knowledge is Essential for Effective Science Teaching

Overview of UNL Longitudinal Study

While each state in the U.S. regulates its own science teacher certification, in the past science education researchers have not produced sufficient research that sets a minimum amount of science coursework, or mastery levels, for teachers. Thus, problematically, even when minimal subject matter knowledge (SMK) state certification requirements have been met, teachers may still hold resistant misconceptions.

Determining teachers' minimum amount of science SMK is challenging as science is multidisciplinary. A limitation of other studies is that only the number of subject area courses and credit hours have been used without using the associated GPA to try to determine SMK mastery (NRC, 2010). Thus, studies that describe the relationship between teachers' SMK and reformed-based teaching practices are essential to improving science education.

In a four-year, multi-method study, we investigated beginning science teachers' SMK, science misconceptions, and instructional practices of undergraduate and master's level science teacher graduates (Lewis et al., 2019). Teachers' SMK was examined by analyzing Misconceptions-Oriented Standards-Based Assessment Resources for Teachers (MOSART) test scores and transcripts. Science lessons were coded and analyzed science lessons using the EQUIP instrument (Marshall, Horton, Smart, & Llewellyn, 2008).

Summary of Key Findings (Lewis et al., 2019)

#1: Teachers' Physical Science Subject Matter Knowledge

Our study's findings about SMK suggest that in order to pass a test of common chemistry or physics misconceptions:

- **chemistry teachers need to take at least 30 credit hours in chemistry at a 3.2 GPA**, and
- **physics teachers need 30 credit hours of physics and mathematics at a 3.0 math GPA.**

#2: Inquiry-Based Instruction

When we investigated the relationship of science SMK and inquiry-based instruction, we found that on average, **teacher graduates from our MA program with undergraduate science degrees taught lessons using twice as much inquiry-based instruction than did undergraduate-program certified teachers without a B.S. in an area of science**. Specifically, new science teachers from the master's program with an undergraduate degree in science were better prepared to use an inquiry-based approach to teaching secondary science.

Recommendations

Based upon our research, UNL has increased all single-subject certifications to 28-30 credit hours in the main content area and 8 credit hours in the other three for a total of 52-54 credit hours. By exceeding the state's minimum standards we will ensure that beginning science teachers from our programs are among the best prepared teachers in the state.