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Results of the Salish Projects: Summary and Implications for Science Teacher Education

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Abstract

Science teaching and teacher education in the U.S.A. have been of great national interest recently due to a severe shortage of science (and mathematics) teachers who do not hold strong qualifications in their fields of study. Unfortunately we lack a rigorous research base that helps inform solid practices about various models or elements of teacher preparation (Allen, 2003; Futrell, 2010; Sykes, Bird, & Kennedy, 2010; Wang, Odell, Klecka, Spalding & Lin, 2010). In reviewing research on science teacher education, Anderson and Mitchener (1994) found that "there is only a small amount of research on pre-service education and what does exist is rather limited in scope and usefulness" (p. 28). A broader review of 37 studies in teacher preparation in general conducted for the U.S. Department of Education (Wilson, Floden, & Ferrini-Mundy, 2001) concluded that "there is no research that directly assesses what teachers learn in their pedagogical preparation or that evaluates the relationship of pedagogical knowledge to student learning or teacher behavior" (p. 12). There have not been enough studies completed of sufficient quality in teacher preparation - in any subject matter area - to provide a confident sense of "what works" and *why it works* (Allen, 2003). Many studies in teacher preparation are case studies or very limited sample size investigations which make generalizations to theory applicable only to these samples, and comparisons among similar populations or programs very problematic (for a more comprehensive review, refer to the Handbook of Research on Science Education edited by Abell & Lederman, 2007).

Key words: Salish Projects, Science Education, Teacher Education.

Introduction

Setting the Context—National Science Education Standards on Teacher Education

Over four years of serious debate about science education reform and inquiry (199296) produced the National Science Education Standards (NSES), which have had an impact in teacher education programs as well as Professional Development projects. The impact now, however, is not as great as one would expect from the seven million dollars spent and the time it took to reach consensus. The Standards provided goals that frame science from Pre-K through grade 12. The first goal was called science for academic preparation for further study of science. This goal was the only one that teachers and schools considered when they prepared a science curriculum and chose a textbook (Harms & Yager, 1981). The stated goals in the Standards began with what can be called inquiry (as the first goal), and completely omitted "academic preparation" as a goal. Of further interest is the fact that "inquiry" also became the first form of content at every level. This inquiry goal indicated that PreK-12 science should educate students who are able to "experience the richness and excitement of knowing about and understanding the natural world." The other three NSES goals for science teaching and learning were to produce students who were able to:

- Use appropriate scientific processes and principles in making personal decisions
- Engage intelligently in public discourse and debate about matters of scientific and technological concern; and
- Increase their economic productivity through the use of the knowledge, understanding, and skills of the scientifically literate person in their careers.

(National Research Council [NRC], 1996, p. 13)

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Ways of achieving these four goals for school science were to be central to exemplary science teacher education programs. However, there was a lack of strong research supporting situations where, what is done in K-12 classrooms moves students to achieving these goals.

Needed emphasis for changing science teaching

The NSES began with visions of changing teaching. The Standards included a Summary Section for each section that identifies conditions needing less emphasis and with needed changes (the More Emphasis conditions). These provided descriptors elaborated in each section of the NSES and indicated the program needs for preparing new science teachers. In the case of teaching, there were nine changes that teacher preparation programs should address if the new teachers are to be ready to accomplish the visions espoused by the NSES leaders:

Less Emphasis	**More Emphasis**
Treating all students alike and responding to responding to the group as a whole	Understanding and responding to individual student's interests, strengths, experiences, and needs and use of scientific knowledge, ideas, and inquiry processes
Focusing on student acquisition of information	Guiding students in active and extended scientific inquiries
Presenting scientific knowledge through lecture, text, and demonstration	Providing opportunities for scientific discussion and debate among students
Asking for recitation of acquired knowledge	Continuously assessing student understanding (and involving students in the process)
Testing students for factual information at the end of the unit or chapter	Sharing responsibility for learning with students
Maintaining responsibility and authority Supporting competition	Supporting a classroom community with cooperation, shared responsibility, and respect
Working alone Focusing on student understanding	Working with other teachers to enhance the science program

Needed changes in professional development programs

The second part of the NSES called for specific changes in Professional Development Programs. These were ways in which teachers should continue to grow and change. These descriptors included:

Less Emphasis	**More Emphasis**
Transmission of teaching knowledge into teaching and learning and skills by lectures	Learning science through knowledge
Separation of science and teaching knowledge	Collegial and collaborative learning
Individual learning	Long-term coherent plans
Fragmented, one-shot sessions	A variety of continuing professional development activities
Courses and workshops	Mix of internal and external expertise
Reliance on external expertise Staff developers as educators	Staff developers as facilitators, consultants, and planners
Teacher as technician	Teacher as intellectual, reflective Practitioner
Teacher as consumer of knowledge about teaching	Teacher as producer of knowledge about teaching
Teacher as follower	Teacher as leader
Teacher as an individual based in a classroom	Teacher as a member of a collegial professional community
Teacher as target of change	Teacher as source and facilitator of change
Integration of science and teaching	

Changing views of student assessment in science

The third call for change in the NSES was the area of Student Assessment. In a similar format, there were descriptors for conditions of less emphasis and more emphasis:

Less Emphasis	More Emphasis
Assessing what is easily measured	Assessing what is most highly valued
Assessing discrete knowledge	Assessing rich, well-structured knowledge
Assessing scientific knowledge	Assessing scientific understanding and reasoning
Assessing to learn what students do what not know	Assessing to learn what students do understand
Assessing only achievement	Assessing achievement and opportunities to learn
End of term assessments by teachers	Students engaged in ongoing assessments of their work and that of others
Development of external assessments by measurement experts alone	Teachers involved in the development and use of external assessments

Broadening the views of science content

One major problem in science education is the discipline segregation that separates physics, chemistry, biology, and earth/space science. Hurd (1986, 1991) argued that this discipline focus only exists in high schools and in undergraduate science areas at colleges and universities. He insisted that most current research focuses more generally on big problems that encompass the whole of science. Research in science arises from real problems and relates to multiple disciplines; it is also more and more tied to technology (and the design world), making these separations among the science disciplines, engineering, technology and design more problematic when addressing science education (AAAS, 2009).

The National Science Education Standards defined the discipline structure as three areas, namely, physical science, life science and earth/space science. A fourth component of science content in the Standards was inquiry (both a form of content as well as the methods of science and science teaching). Four other facets of content illustrated this broader view:

A. Technology: A focus on the design world instead of only the natural world. Both science and technology engage many of the same procedures. They differ in that the desired results and the designs are known already in technology-but the results of investigating in the science world are only known after investigations are completed.
B. Science for meeting personal and scientist challenges: This illustrates the use of problems as the beginning place and the organization of science instruction.
C. History and Philosophy of Science: This includes Sociology of Science and a world view of what science is as a human activity over time and within varying cultures.
D. Science concepts and processes in concert: This is the first and over-arching form of content. The Standards were the first to illustrate the importance of holistic thinking in place of the concepts of science (in the disciplines) and specific acts of inquiry. The eight facets of content are: Unifying concepts and processes in science; science as inquiry; physical science; life science; earth/space science; science and technology; science in personal and social perspective; and history and nature of science.

The fourth major section of the NSES generated the most debate and interest- defining specific content. Unfortunately many educators ignored aspects of the first parts and skipped to the content — the "stuff' of the curriculum. Once more, the focus was on inquiry per se» Overarching ideas and concepts took precedence over the minutiae that typify too many science classes. These changes in defining science content were to be central in all science teacher preparatory programs.

Key Findings of Salish I: Science Teacher Education at Ten Universities

Salish was an exploratory study conducted to uncover knowledge about the relationship between secondary science and mathematics teacher preparation, new teacher knowledge, beliefs, and performances; and. student learning outcomes. It was through these kinds of efforts that the science and mathematics education communities could address the needs of students, teachers, teacher educators, and other stakeholders working to establish a common vision for excellent instruction and systemic, long-lasting reform. The Salish I research project was funded by the U.S. Department of Education in 1993 and completed in June 1997. 'fen diverse universities were chosen by the Office of Educational Research and Improvement. A sample of ten teachers were selected as new graduates from the universities; later 10 additional teachers were chosen to complete the sample over four years of funding.

A project focus on changes in teacher knowledge and beliefs was matched to performances with what was espoused in the preparatory programs. The research examined progress during the preparatory program for one sample (pre-service teachers) and another (beginning in-service teachers) through their first four years of teaching.

A. Student Outcomes (Students of Salish teachers)

- Students were much more likely to believe they could express their opinions about classroom instruction than believed they could actually play a role in the decision making about that instruction.
- Student perceptions of their classroom learning environments were associated with the level of community affluence and gender.
- Students in middle socioeconomic status communities believed they had fewer opportunities to voice their opinions about instruction than did students from both communities of higher and lower socioeconomic status.
- Science classes having a majority of females displayed more peer verbal interactions than did classes with gender balance. In classes with mostly females, there were more opportunities for evaluating the appropriateness of instruction.
- Popularly held views of students, classrooms, and schools were overly simplistic. The results indicated that every student, classroom, and school was unique and interactions among them very complex.
- Collecting student data was extraordinarily problematic. Problems include logistical and legal concerns. These problems led to a high attrition rate of research participants.

B. New Teachers (Salish participants)

- Teachers graduated from their teacher preparation programs with a range of knowledge and beliefs about:
  - how teachers should interact with subject content and
  - processes
  - what teachers should be doing in the classroom
  - what students should be doing in the classroom
  - philosophies of teaching; and
  - how they perceived themselves as classroom teachers.
- New teachers described their practices as very student-centered.
- Observed teaching practices contrasted starkly with teacher beliefs: while teachers professed student centered beliefs, they behaved in teacher-centered ways.
- Classroom practices of third year teachers converged more closely with their beliefs; their observed actions became more student centered and their beliefs became more teacher-centered.
- New teachers reported a lack of coherence among the various features of their programs.
- High demands on teachers' time caused many problems with data collection which led to a high attrition rate of research participants.

C. Preparation Programs

- Each new teacher candidate completed a unique teacher preparation program because of differences in their backgrounds and experiences.
- Although formal program features reflected wide variations, common experiences for certification included:
  - a major in the content area (ranging from 21-60 semester hours);
  - a subject-specific methods course;
  - an educational psychology course; and
  - a field-based student teaching/internship experience ranging from 10 to 36 weeks.
- New teachers often perceived little or no connection between what was advocated and what was practiced in their content and teacher education courses.

- Faculty in science, mathematics, and teacher education viewed teacher preparation programs as lacking coherence.

D. Linkages (Students, Teachers, and Programs)

- Linkages were evident between:
  - informal and formal preparation program features; a subject-specific methods course;
  - new teachers' knowledge and belief systems and classroom performances, and performance of their secondary school students.

- Students taught by new teachers with scientific research experiences or prior careers perceived their science classes as relevant to their personal lives.
- Students taught by new teachers with scientific research experiences or prior careers saw science and mathematics as tentative or uncertain.
- Students taught by teacher-centered teachers thought their science classes were relevant to the world outside of school.
- Students who behaved in student-centered ways were t-aught by new teachers who held a coherent student-centered philosophy of teaching.
- Student-centered actions were not observed in classes taught by new teachers whose philosophies of teaching were not coherent with their practices.
- Students who believed that they shared control of the learning environment were taught by new teachers with a teacher-centered philosophy of teaching.
- Conceptual teachers were concerned about their subject content and value reflection of professional involvement.
- New teachers with student-centered beliefs completed programs that included at least nine semester credit hours of subject-specific methods: courses.
- New teachers who had practice with student-centered classrooms completed programs which included at least 30 weeks of student teaching experience.
- New teachers holding student-centered beliefs were likely to have completed teacher preparation programs in which they:
  - engaged in cooperative learning; a subject-specific methods course;
  - were assessed through papers and evaluations of actual teaching performance in the field
  - were part of a formal cohort in teacher education; and
  - had strong, close personal relationships with faculty.

- Teachers who held student-centered, beliefs were more likely to have completed a longer student teaching experience. When teachers completed nine or more credit hours of subject-specific methods, they were more likely to be student-centered in their classroom practices.
- New teachers holding teacher-centered beliefs about subject content held negative impressions of their teacher education study, while those holding student-centered beliefs about subject content held more positive impressions of their teacher education study.

E. Project Accomplishments

Two of the major Salish goals were to uncover relationships between preparation and teacher and student outcomes, and to learn how to study these relationships more formally. Another goal was to operate collaboratively and learn about the processes and benefits of collaboration. The multiple goals and the nature of the research study itself led to a Project that was extremely challenging and lU1Usually rich in potential impact. There were other major accomplishments of the Salish effort that promised to contribute to improving the quality of secondary science and mathematics teacher preparation:

- the study data and findings guided teacher preparation program reforms in the participating universities;
- project participation was a powerful professional development experience for both Faculty and Research Associates;
- the project modeled collaborative research;
- participating in Salish moved forward science and mathematics educators' understandings of the relationships between teacher preparation and outcomes and how to study these relationships; and

- the Salish project contributed to a national interest and dialogue about the quality of teacher preparation programs in science and mathematics.

Key premises and Findings of Salish II

The ten basic premises of Chautauqua ISTEP (Robinson & Yager, 1998) (also known as Salish II) were linked to the Salish I conclusions, the Thinking Movement, the National Science Education Standards (NRC, 1996). and the template for "best practices" in teaching and learning. These premises were:

A. Most Teacher Education Programs (TEP) did little to promote logical thinking (most successful students were only attentive and conscientious about remembering information).
B. All reforms in teacher education programs should be based on the National Science Education Standards (the kinds of classroom teaching and professional development efforts needed to promote the reforms are carefully described in NSES).
C. The NSES called for limiting die quantity of content in secondary schools; the NSES also recognized eight facets of content, including life, physical, and earth/space science (the three traditional area of content), science inquiry, science and technology, science for meeting personal and societal challenges, the nature and history of science, and unifying and using science concepts and processes.
D. The Chautauqua model for improving TEP (Robinson & Yager, 1998) project urged a focus on the reform agenda (NSES) in terms of content, teaching, and thinking.
E. The thinking skills component for the Chautauqua TEP effort should be an integral part of the whole instructional and action research package; it should not be a stand-alone or as one distinct facet of the workshop (thinking, or thinking skills, emerged as important from the Salish research but little was done with the research or gathering specific data to document thinking skills in most programs).
F. Assessment should be central to the Chautauqua effort; again, the NSES provided rich information.
G. The Chautauqua for Teacher Education Programs attempted to model effective instruction, curriculum development, and assessment as one way of illustrating changes that could occur on the campuses in the programs and experiences for pre-service teachers.
H. New teachers and experienced teachers who understand the NSES and the thinking research should be employed as vital partners in the instruction for workshops for teachers.
İ. The instruction in the CTEP workshop, the models provided, the plans for implementing change must exemplify the basic principles of science, namely, questioning, explaining, testing the explanations for validity, and sharing evidence with peers.

In summary, the aspects of teaching thinking emphasizing learning and understanding via the processes of critical thinking, decision-making, applications (Tishman & Perkins, 1997) were used within the programs themselves.

Salish Research on Provisional or Alternative licensure programs

A third effort extending from the Salish I research was an examination of differences between science teachers licensed through a campus-based program and those teachers given provisional programs (most preparation completed on-the-job with major input from the existing teacher cadre) (Robinson & Yager, 1996). Some generalizations from this effort included the following:

- Teachers from alternative licensure programs tended to remain more closely tied to curriculum guides and textbooks.
- Teachers from alterative programs tended to be much more science discipline oriented.
- Teachers who did. not complete more typical college programs tended to minimize the importance of campus programs and stress their better science preparation - and often their experiences in other careers.
- Teachers prepared in alternative programs were often more interested in assistance from other teachers and administrators.
- Teachers from alternative programs were often less involved professionally.
- Teachers from alternative programs found it difficult to pinpoint specific features from their preparatory programs that affected their teaching.
- Teachers from alternative programs often cited their experiences in other careers as helpful in the classroom. These experiences provided new contexts and reasons for science learning.
- Teachers from alternative programs were quick to cite limitations of their collegiate experiences - even those related to the science and mathematics courses they had completed.

- Teachers from alternative programs often held negative views about specific help they requested from college teacher education programs. They found the staff to be inflexible - and often unable to help their transitions to the classrooms.
- Alternative teachers were critical of college experiences in the sciences - described as a collection of more facts formatted directly for their use in teaching.
- Alternative certification programs in which candidates gained the most content knowledge and knowledge about teaching reading and mathematics were the programs in which they had frequent opportunities to observe several master teachers, and then discuss both the content and the pedagogical strategies.

Impact of Salish Projects

Teacher Education Program Renewal

The requirements for universities participating in the various Salish Projects to belong to the Salish cohort stimulated some universities to convene faculty teams with a wide span of potential program influence. Universities invested their own financial and personnel resources to participate in the Project; commitment to applying the research results was secured "up front,'5 Teams were visible on-campus, and the visibility created expectations. The teams selected topics or areas of concern for which they were already accountable for program performance.

For example, three universities established new science teacher education programs and looked to the faculty team to evaluate the effectiveness of these programs. The perceived association with the Salish I Research Project lent exceptional credibility to the plans of the university teams that were formed to change their university programs. One residual for the new teams was a greater reliance on data-based decision making. Salish team, members admitted that many of the program modifications they made in the past (before Salish) were not based on evaluation and research data gathered systematically over time.

Inter-University Projects: Common Features

Among the very important features of successful projects (such as the Salish series) that brought together universities from all regions of the nation were the following:

A. The Project epitomized a learning community, i.e., a "safe place where they could say, explore, and disagree about anything without [adverse] consequences" and where peers were encouraged to expose problems and learn from one another.
B. University teams bridged science education and teacher education and administration; teams identified common areas of concern for what all members were committed to address.
C. Resources (identified as funding, instrumentation, and expertise using particular research techniques) were available to carry out team activities.
D. The Project was characterized by product requirements and ambitious timelines that were motivating rather than overwhelming.

Insights from Salish Final Conference

Analysis of the discussions held at the Salish Final Conference in May, 1998, revealed the clues and keys for reforming the practice of educating science pre-service students. They are arranged under the categories including: reasons for reform, how to further the change process, and an elaboration of research evidence required for effectiveness in teacher pre-service and in-service education.

A. Reasons for reform

- Impacting pre-service teacher preparation facilitated the implementation of standards- based curricula and practice in mathematics and science teaching;
- The incorporation of thinking research into teacher preparation enabled teachers to examine and experience constructing knowledge through one's own thinking processes, and gave teachers the tools for providing their students with opportunities to think;
- The strong imprinting in K-16 education led people to teach the way they were taught regardless of the effects of pre-service methods classes.

B. Furthering the change process

- Developing trust between change agents and those involved in essential tasks took time to develop.
- Creating a sense of urgency and a sense of vision were helpful to start collaboration as long as urgency did not lead to "band-aid fixes."
- Persuading scientists to use the research evidence that was collected and available informed their instruction.
- Defining relevant arguments for change among people who were not necessarily involved in science teacher education (e.g., the general public, legislators, scientists) helped the case for science teacher education.
- Justifying the change process with the added perspectives from social justice issues for underrepresented groups within science education at every level strengthened the argument for science teacher education.

Using video offerings that showed similar problems in science education at universities built their reputations with their selectivity of only the best students (e.g., The Private Universe, Annenberg tapes, and tapes from the Derek Bok Center) helped change the common view held by science professors that student deficiency was "the problem."

C. Recommendations for follow-up actions

- Document what was working currently in pre-service science education.
- Substantiate change in programs with ongoing evidence that students were responding in the manner hypothesized.
- Refine further instruments such as the Nature and Implications of Science Teaching (NIST) to assess understanding by practicing teachers, pre-service teachers, and students about the nature of science.
- Learn more about the people being prepared for science teaching.
- Determine why attrition was so high in the first five years of science teaching. Provide specific support structures to moderate attrition.
- Establish the need for best practices in mathematics and science courses at the undergraduate level (most of which have not changed in format over 30 years, Blunck, Giles, and McArthur, 1993; Robinson and Yager, 1996).
- Make accurate comparisons and contrasts between the situations of U.S. and International science education that illustrate both the products and the processes that create the learning product in children (as begun by the TIMSS studies).
- Develop plans to institute and measure progress in inquiry at all levels K- graduate school (Melear, Hickok, Goodlaxson, and Warne, 1998).

Implications of Salish Findings of Conclusions and Implications of Salish Findings

All of the research and the visions included in the National Science Education Standards produced arguments for teacher education programs that showed the most promise for the kind of quality science teachers envisioned. For universities with a semester organization the following plan is recommended as providing the most promise for success in preparing science teachers for the future.

- A strong science component consisting of a major science area (30 + s.h.) and a supplementary area (at least 15 s.h.).
- Specific work in the history, philosophy, sociology of science (6 s.h.).
- An introduction to the design world (technology) and its ties to the natural world (6 s.h.).
- Experiences (one semester each) with applications of science, including work with current issues (guiding questions, possible explanations, selection of "best fit" solutions, corrective actions. (12 s.h.)
- A science and a technology research experience.
- A methods sequence with a practicum experience in schools followed with full time student teaching (over 4 semesters).
- University general education requirements for Bachelor Degrees sequence (about 30 s.h.).
- General Education (philosophy of education, educational psychology, special education, diversity, action research).
- (10 s.h.)

The ideal program cannot be completed in a typical Bachelor's program. For undergraduates, it is usually necessary to complete one summer session in addition to the 8 semesters or 4 academic years. Since many students decide on teaching after completing undergraduate degrees, they can enroll in MAT or M.S. programs. These programs allow persons with strong undergraduate science degrees to complete the needed courses and field experiences in one full year and two summers.

Historically at the undergraduate level, more interest has been focused on the level of teaching rather than the level of ¡earning of students. A focus toward learning must be developed and applied by collaboration among scientists, science educators, and pre-service students (and all students). Dialogue with a person who regularly practices active learning strategies for support of progressive teaching tactics is very important for both 1) ideas to assist in development of the lesson plans, and 2) for making adjustments after trying the practice for the first few times. Mechanisms for reflective practices must be set into cooperative action. The various disciplines have different cultures that require productive communication to accomplish change in which many people have ownership.

Differences in some states for middle vs. high school teaching and some variations among the traditional science disciplines continue to be separated as departments in colleges and universities, even though there is little research supporting these kinds of specific recommendations. The recommendations offered from these projects provide a framework for achieving the kind of teaching and continuous learning required for effective science teachers. These recommendations take into account the reforms recommended in the National Standards and elevate thinking beyond defining pedagogical knowledge and increasing requirements in the basic science in most colleges.. In summary, as a community of science teacher educators and science educators, we must continue to improve the quality of our teacher education programs based upon rigorous research about teaching, learning, and institutional change, so we can address the needs of our science teachers and prospective teachers in the 21Century.

References

Allen, M. (2003). Eight Questions on Teacher Preparation: What Does the Research Say? Denver, CO. Education Commission of the States.

Abell, S. & Lederman, N. (Eds.) (2007). *Handbook of Research on Science Education.* Mahwah, NJ, Lawrence Erlbaum Associates Publishers.

American Association for the Advancement of Science. (2009). *New Challenges, New*

Strategies. Building Excellence in Undergraduate STEM Education. Arlington, VA. National Science Foundation.

Anderson, R. D., & Mitchener, C. P. (1994). Research on science teacher education. In D. L. Gabel (Ed.), *Handbook on science teaching and learning* (pp. 3-44). New York: MacMillan.

Appleton, K., & Kindt, I. (2002). Beginning elementary teachers' development as teachers of science. *Journal of Science Teacher Education,* 13(1), 43--61.

Baron, lB., & Wolf, D. (1996). *Performance-based student assessment. challenges and possibilities.* Yearbook of the National Society for the Study of Education (95th, pt. 1). Chicago: NSSE.

Bianchini, lA., & Solomon, E.M. (2003). Constructing views of science tied to issues of equity and diversity: A study of beginning science teachers. *Journal of Research in Science Teaching,* 40(1), 53-76.

Bransford, J. (2000). *How people learn: brain, mind, experience, and school.* Washington, D.C.: National Academy Press.

Blunck, S. M., Giles, C. S., and McArthur, J. M. (1993). Gender differences in the science classroom: STS bridging the gap. In R. Yager (ed.). *What research says to the science teacher: Volume* **7,** *The science***,** *technology, society movement* (pp. 153-169). Washington. D.C.: National Science Teachers Association.

Chin, P., & Russell, T. (1995). Structure and coherence in a teacher education program: Addressing the tensions between systemics and the educative agenda. Paper presented at the annual meeting of the Canadian Society for the Study of Education. Montreal, Quebec, Canada

Cognition and Technology Group at Vanderbilt. (2000). Adventures in anchored instruction: Lessons from beyond the ivory tower. *In R. Glaser (Ed.), Advances in instructional psychology, Vol. 5. Educational Design and Cognitive Science* (pp. 35-99). Mahwah, NJ: Erlbaum.

Cohen, D. K. & Hill, H. G. (2000). Instructional policy and classroom performance: The mathematics reform in California. Teachers College Record, 102(2), 294-343.

Cohen, D. K., & Hill, H. C. (2001). Learning policy: When state education reform works. Yale University Press.

Druva, C.A., & Anderson, R.D. (1983). Science teacher characteristics by teacher behavior and by student outcome: A meta-analysis of research. *Journal of Research in Science Teaching, 20*(5), 467-479.

Crawford, B.A. (1999). Is it realistic to expect a preservice teacher to create an inquiry-based classroom? *Journal of Science Teacher Education,* 10(3), 175-194.

Danielson, C. (1996). Enhancing professional practice: A framework for teaching. Alexandria, VA: Association for Supervision and Curriculum Development.

Darling-Hammond, L., & Macdonald, M. (2000). Where there is learning there is hope: The preparation of teachers at the Bank Street College of Education. *In L. Darling-Hammond (Ed.),* Studies of excellence in teacher education: *Preparation in a five-year program* (pp. 1-95). Washington, DC: American Association of Colleges for Teacher Education.

Druva, C. A. & Anderson, R. D. (1983). Science teacher characteristics by teacher Behavior and by student outcome: A meta-analysis of research. *Journal of Research in Science Teaching,* v20; n5; (pp. 467-479),

Eick, C.J. (2002). Job sharing their first year: A narrative of two partnered teachers' induction into middle school science teaching. *Teaching and Teacher Education,* 18(7), 887-904.

Ferguson, P., & Womack, S.T. (1993). The impact of subject matter and on teaching performance. *Journal of Teacher Education,* 44(1), 55-63.

Futrell, M. (2010). Transforming Teacher Education to Reform America's P-20 Education System. *Journal of Teacher Education,* 61, 432-440.

Goldhaber, D.D., & Brewer, D.J. (1997). Why don't schools and teachers seem to matter? Assessing the impact of unobservables on educational productivity. *The Journal of Human Resources,* 32(3), 505-523.

Goldhaber, D.D., & Brewer, D.J. (2000). Does teacher certification matter? High school teacher certification status and student achievement. *Educational Evaluation and Policy Analysis,* 22(2), 129-145.

Harms, N. C., & Yager, R. E. (1981). What research says to the science teacher. Washington: National Science Teachers Association.

Humphrey, D.C., Wechsler, ME.. & Hough, H.J. (2008). Characteristics of effective alternative teacher certification programs. *Teachers College Record* 110(1), 3-23.

Koppich, J. (2000). Trinity University: Preparing teachers for tomorrow's schools. *In L. Darling-Hammond (Ed.),* Studies of excellence in teacher education: *Preparation in a five-year program* (pp. 1-48). Washington, DC: American Association of Colleges for Teacher Education.

Koppich, J., Merseth, K. K., & Darling-Hammond, L. (2000). *Studies of excellence in teacher education: preparation in a five-year program*. Washington, *DC:* AACTE Publications.

Liebennan, A., & Wood, D. (2003). *Inside the National Writing Project. connecting network learning and classroom teaching. The series on school reform.* New York: Teachers College Press.

Lopez, A., Lash, A., Schaffner, M., Shields, P., & Wagner, M. (2004). *Review of research on the impact ofbeginning teacher induction on teacher quality and retention*. Menlo Park, CA: SRI International.

Loughran, J. (1994a). Bridging the Gap: An Analysis of the Needs of Second Year Science Teachers. *Science Education, 78*(4), 365-386.

Loughran, J. (1994b). *Learning how to teach. Unpacking a teacher educator's thinking about pedagogy in pre-service education* Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans, LA.

Luft, .I.A., Bragg, .I., & Peters, C. (1999). Learning to teach in a diverse setting: A case study of a multicultural science education enthusiast. *Science Education, 83*(5), 527-543.

Luft, .I.A., Roehrig, G.H., & Patterson, N.C. (2003). Contrasting landscapes: A comparison of the impact of different induction programs on beginning secondary science teachers' practices, beliefs, and experiences. *Journal of Research in Science Teaching, 40*(1), 77-97.

Lumpe, AT, Haney, .J.J., & Czerniak, C.M. (2000). Assessing teachers' beliefs about their science teaching context. *Journal of Research in Science Teaching,37*(3), 275-292.

Melear, C. T., Hickok, L. G., Warne, T. R., & Goodlaxson, J. D. (1998). Responses of preservice secondary science teachers to learning science in an apprenticeship: The research experience (RE). In J. B. Robinson and R. E. Yager (Eds.), Translating and using research for improving teacher education in science and mathematics (pp. 26-35). The Final Report from the OERI-funded Chautauqua ISTEP Research Project. The University of Iowa.

Monk, D.H. (1994). Subject area preparation of secondary mathematics and science teachers and student achievement. *Economics of Education Review, 13*(2),125-145.

Monk, D. H., & King, J. (1994). Multilevel teacher resource effects on pupil performance in secondary mathematics and science: The role of teacher subject-matter preparation. In R. G. Ehrenberg (Ed.), *Contemporary policy issues: Choices and consequences in education* Ithaca, NY: IRL press.

Munby, H., Russell, T., & Martin, A. K. (2001). Teachers' knowledge and how it develops. In V. Richardson (Ed.), *Handbook of research on teaching* (pp. 877-904). Washington, DC: American Educational Research Association.

National Research Council. (1996). *National Science Education Standards: Observe, interact, change, learn.* Washington, DC: National Academy Press.

National Research Council. (2007). Initial draft Committee on Science and Mathematics Teacher Preparation. Washington, DC: National Academy Press.

Perkins, D. N. (1992). *Smart schools.* New York: The Free Press.

Raphael, J., Tobias, S., & Greenberg, R. (1999). Research experience as a component of science and mathematics teacher preparation. *Journal of Science Teacher Education, 10*(2), 147-158.

Robinson, D. &Yager, R. E. (1996). *A descriptive study of teachers from alternative certification programs.* Final Report to The John D. and Catherine T. MacArthur Foundation, Chicago, Illinois.

Robinson,T. B. & Yager, R. E. (1998). *Translating and using research for improving teacher education in science and mathematics.* Final Report from the OERI-funded Chautauqua ISTEP Research Project (Salish II). Supported by the Office of Educational Research And Improvement, U.S. Department of Education (Grant No. RI68U60001).

Salish I Research Project (1997). *Secondary science mathematics teacher Preparation programs: Influences on new teachers and their students.* (Final report). Washington DC: U.S. Department of Education and Office of Educational Research and Improvement.

Simmons, P. E., Emory, A., Carter, T., Coker, T., Finnegan, B., Crockett, D., ... & Labuda, K. (1999). Beginning teachers: Beliefs and classroom actions. *Journal of Research in Science Teaching*, *36*(8), 930-954.

Sumara, OJ., Luce-Kaper, R. (1996). (Un)Becoming a teacher: Negotiating identities while learning to teach. *Canadian Journal of Education, 21(1),* 65 -83.

Synder, J. (2000). Knowing Children—Understanding Teaching: The developmental teacher education program at the University of California, Berkeley. In L. Darling-Hammond (Ed.), *Studies of excellence in teacher education: Preparation in a five-year program,* (pp. 97-172). Washington, DC: American Association of Colleges for Teacher Education.

Sykes, G, Bird, T., & Kennedy, M. (2010). Teacher education: Its problems and some prospects. *Journal of Teacher Education,* 61 , 464-476.

Teacher Education and Learning to Teach (TELT) (1986). Michigan State University, East Lansing, MT.

Tishman, S., & Perkins, D. (1997). The Language of Thinking. *Phi Delta Kappan.* 78(5), 368-74.

Tobin, K., & LaMaster, S.U. (1995). Relationships between metaphors, beliefs, and actions in a context of science curriculum change. *Journal of Research in Science Teaching,* 32(3),225-242.

Wang, .T., Odell, S., Klecka, C., Spalding, E., & Lin, E. (2010). Understanding teacher education reform. *Journal ofTeacher Education*, 61 , 395-402.

Weld, J.D., & French, D.P. (2001). An undergraduate science laboratory field experience for pre-service science teachers. *Journal of Science Teacher Education*, *12*(2), 133-142.

Whitford, B.L., Ruscoe, G., & Fickel, L. (2000). Knitting it all together: Collaborative teacher education in Southern Maine. In L. Darling Hammond (Ed.), *Studies of excellence in teacher education: Preparation in afive-year program* (pp. 173257). Washington, DC: American Association of Colleges for Teacher Education.

Wiggins, G. P., & McTighe, J. (1998). *Understanding by design.* Alexandria, Va: Association for Supervision and Curriculum Development.

Wilson, S. M., Floden, R. E., & Ferrini-Mundy, 1. (2001). *Teacher preparation research: Current knowledge, gaps, and recommendations.* Research report prepared for the U.S. Department of Education by the Center for the Study of Teaching and Policy in collaboration with Michigan State University.

Windschitl, M. (2004). Caught in the cycle of reproducing folk theories of "Inquiry": How pre-service teachers continue the discourse and practices of a theoretical scientific method. *Journal of Research in Science Teaching, 41*(5), 481-512.

Windschitl, M., & Thompson, J. (2006). Transcending simple forms of school science investigations: Can pre-service instruction foster teachers' understandings of model-based inquiry? *American Educational Research Journal, 43*(4), 783-835.

Windschitl, M., Thompson, J., & Braaten, M. (April 2008). *The development of pedagogical expertise: Tracking novice science teachers across learning contexts in their first three years.* Paper presented at the annual meeting of the American Educational Research Association: New York, NY.

Zembal-Saul, C., Munford, D., Crawford, B., Friedrichsen, P. & Land, S. (2002). Scaffolding preservice science teachers' evidence-based arguments during an investigation of natural selection. *Research in Science Educa/ion, 32*(4), 437-46.