Importance of characterizing STEM faculty members’ instructional mindsets and practices in an era of instructional transformation

Marilyne Stains
Associate Professor
Department of Chemistry
University of Nebraska-Lincoln
@MarilyneStains

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Research-based instruction can address national priorities

- **Persistence** of students in STEM fields and the preparation of a science-literate society are national priorities.

- The learning environment provided in STEM courses is an important **lever** to achieve these goals.

- Research has demonstrated that certain instructional approaches can enhance student learning, attitude and persistence in STEM.

**Fact:**
Less than half of students entering colleges intending to major in STEM fields graduate with a STEM degree.

**Fact:**
Students often leave STEM because of the uninspiring instructional practices experienced in introductory courses.


There have been numerous initiatives to reform teaching

- Initiatives to transform instruction in STEM undergraduate courses have been on-going for decades.

**SCIENCE EDUCATION**

*Challenge faculty to transform STEM learning*

Focus on core ideas, crosscutting concepts, and scientific practices


At present, however, policy makers and the public do not know whether these various initiatives are accomplishing their goals and leading to nationwide improvement in undergraduate STEM education.* (p.1)

- A recent study provides some insight.

**Measuring the level of uptake is challenging**

Context of study

• Common instructional profiles can be identified among a population of STEM instructors.

• Expansion of the study helps explore generalizability of these profiles.

Methods

Instrument

• COPUS: Classroom Observation Protocol for Undergraduate STEM


Data Analysis

• Latent profile analysis using 8 codes:
  • Instructor: lecture, posing questions, clicker questions, and one-on-one work with students
  • Students: group work on clicker questions, group work on worksheets, other group work, and asking questions

Three broad instructional styles were observed

- Seven clusters were identified which can be categorized in three broad categories:
  - Didactic
  - Interactive lecture
  - Student-centered

- Didactic was the most observed style.

Minimal transformation was observed in the STEM curriculum

- Didactic teaching dominates across the curriculum and across STEM disciplines.

Why is change not happening?

Discipline-Based Education Research Products
- Student Learning Processes
- Instructional Materials
- Pedagogies
- Assessments

Gap

STEM Instructional Practices

Why is change not happening?

DBER scholars have focused on R&D and dissemination

- The focus has been on leveraging research on student learning to develop, test, and disseminate new curricula and instructional practices.
- Dissemination increases awareness but not necessarily adoption of these products.


In DBER, we have focused on R&D and dissemination

- The focus has been on developing, testing and disseminating through workshops new curricula and instructional practices.
- Dissemination increases awareness but not necessarily adoption of these products.

Instructors are the bridge between research and practice
Yet, we know little about faculty’s thinking about teaching

- Faculty-focused studies in chemistry education research have been limited.

Focus of CER studies (N=650; 2004-2013)

- Pre/in-service teachers 17%
- K-12 37%
- Undergraduates, postgraduates, as well as textbooks used at the university level 45%
- Faculty 1%


Many factors impact faculty’s instructional decisions

Personal Factors
- Demographic profile
- Types and years of teaching experience
- Nature and extent of teachers’ preparation to teach
- Nature and extent of teachers’ continued learning efforts

Teacher’s Thinking
- Teaching beliefs
- Dissatisfaction
- Self-efficacy
- Pedagogical content knowledge

Contextual Factors
- Broader Cultural Context
- Institutional Context
- Departmental and Subject Area Context
- Classroom Context

Faculty’s Instructional Practice


Illustrative example

- Collected surveys and classroom observations from a representative group of faculty from a chemistry, biology and physics department at one research-intensive institution.

<table>
<thead>
<tr>
<th>Pedagogical Experience</th>
<th>Attitudes toward student-centered teaching</th>
<th>Departmental norms toward student-centered teaching</th>
<th>EBIPs knowledge and use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemistry</td>
<td>Limited</td>
<td>Negative</td>
<td>Weak</td>
</tr>
<tr>
<td></td>
<td>Knowledge: 62%</td>
<td>Use: 11%</td>
<td></td>
</tr>
<tr>
<td>Biology</td>
<td>Moderate</td>
<td>Positive</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>Knowledge: 65%</td>
<td>Use: 19%</td>
<td></td>
</tr>
<tr>
<td>Physics</td>
<td>Extensive</td>
<td>Positive</td>
<td>Strong</td>
</tr>
<tr>
<td></td>
<td>Knowledge: 68%</td>
<td>Use: 33%</td>
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</tr>
</tbody>
</table>


Promoting change is complicated

[Image of a scientific article]

We need to understand our faculty

Science Faculty
= Discipline-Based Education Research Learners

Science Learners

- Student-focused investigations
  - Conceptual understanding and conceptual change
  - Problem solving & Science and engineering practices
  - Instructional strategies to improve STEM learning
  - Metacognition
  - Students’ dispositions and motivations to study STEM

- Faculty-focused investigations
  - Conceptual understanding and conceptual change
  - Instructional decisions and skills when planning and teaching
  - Strategies to improve STEM teaching
  - Reflective practice
  - Faculty’s dispositions and motivation to implement research-based instruction

Overall research question: How do STEM faculty plan the teaching of a week of content and how do they reflect on this experience?

Scientific Teaching

• Key characteristics of Scientific Teaching:
  • A scientific teacher has explored the breadth of reasons why we teach science.
  • A scientific teacher evaluates learning regularly and makes teaching decisions based on evidence.
  • Scientific teaching is an iterative process of review and revision.
  • Active learning, assessment, and diversity are core themes of scientific teaching.
Scientific Teaching Framework

1. Create Learning Goals
   What should students know and be able to do after instruction?

2. Determine Evidence for Learning
   How will progress toward learning goals be gauged?

3. Planning Learning Experiences
   How will students be engaged in pursuit of the learning goals?

4. Evaluation, Review, and Revision
   What were the outcomes of the instruction? What could be done differently going forward?

Research Questions

• What types of learning goals do postsecondary STEM instructors have for their students?

• How do postsecondary STEM instructors plan to assess achievement of learning goals?

• What learning experiences do postsecondary instructors plan to use to help students achieve the learning goals?

• To what extent are postsecondary instructors satisfied with their teaching?

• What types of revisions do postsecondary instructors plan to implement in the next execution of the course?

• What relationships exist between postsecondary instructors’ level of satisfaction with their teaching and their intent for instructional change?
Pedagogical Content Knowledge


Methods: Context

- Doctoral University — Highest Research Activity institution in the Midwest
- Evaluation of workshop series intended to teach STEM faculty about Peer Instruction and Just-in-Time Teaching
Methods: Participants

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Percentage of instructors</th>
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</thead>
<tbody>
<tr>
<td>Treatment Status</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>26</td>
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<tr>
<td>PI</td>
<td>43</td>
</tr>
<tr>
<td>JITT</td>
<td>31</td>
</tr>
<tr>
<td>Class Size</td>
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</tr>
<tr>
<td>1 to 25</td>
<td>24</td>
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<tr>
<td>26 to 50</td>
<td>19</td>
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<tr>
<td>51 to 100</td>
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<tr>
<td>101 through 150</td>
<td>12</td>
</tr>
<tr>
<td>151 plus</td>
<td>26</td>
</tr>
<tr>
<td>Course Level</td>
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</tr>
<tr>
<td>Lower Undergrad</td>
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<tr>
<td>Upper Undergrad</td>
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<td>Graduate</td>
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<tr>
<td>Course Discipline</td>
<td></td>
</tr>
<tr>
<td>Biology</td>
<td>38</td>
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<tr>
<td>Chemistry</td>
<td>24</td>
</tr>
<tr>
<td>Math</td>
<td>10</td>
</tr>
<tr>
<td>Physics</td>
<td>10</td>
</tr>
<tr>
<td>Other (7 disciplines)</td>
<td>19</td>
</tr>
<tr>
<td>Experience (years)</td>
<td></td>
</tr>
<tr>
<td>0 to 6</td>
<td>21</td>
</tr>
<tr>
<td>7 plus</td>
<td>79</td>
</tr>
</tbody>
</table>

Methods: Data Collection

- Data was collected before implementation of the workshop series.

Pre interview questions
1. What are your learning goals for students this week?
2. How do you plan on engaging students into the content? What specific teaching techniques do you plan to use in the class?
3. How do you plan to assess students’ achievement of your learning goals?
Methods: Data Collection

- Data was collected before implementation of the workshop series.

Post interview questions:
1. To what extent did you meet your goals this week?
2. Did the students learn what you intended them to learn? How do you know?
3. Were you satisfied with students’ engagement this week?
4. What would you do differently if you were to teach this class again?
5. To what extent were you satisfied with your teaching strategy this week?
Methods: Data Analysis

- All authors contributed to the development of the code book (~200 codes).
- Most codes emerged from the data through an iterative process.
- The unit of analysis was the instructor’s full response to an interviewer’s question.
- Five of the transcripts were coded by two authors.
- The mean pooled kappa value for the five transcripts was 0.864.
- Both authors coded the rest of the interviews independently.
- Code book was eventually reduced based on frequencies of codes. Final code book includes 49 codes.

Learning goals

- Learning goals should address core ideas, cross-cutting concepts, and scientific and engineering practices.
- Learning goals should engage students at various cognitive levels.

Bloom’s taxonomy


Learning goals

- Most faculty (98%) answered the questions by listing topics.
- Most (88%) also provided goals that could be bloomed. Majority of those were at the lower cognitive levels.
- Results are consistent with other BER studies.

![Bloom's Taxonomy Chart]


Planned assessment

- Two main types of assessment are used:

  ![Formative Summative Diagram]

  - Research has demonstrated the positive impact on student learning of formative assessments.
  - National reports advocate for wide implementation of formative assessments.

Summative assessments are more commonly used than formative assessments.

Learning experiences

- Instructors use lecture and questioning mostly.
- 90% mentioned at least three engagement strategies, and 60% described at least four separate strategies.
Clickers highlight gaps in faculty’s knowledge of assessment

- A fifth of the faculty thought of clicker questions as an engagement tool but not an assessment tool:

> “I don’t really use clicker questions to assess their learning. [Students] use clicker questions to assess their learning, and I use my lecturing. I assess their learning on exams. I don’t really care if they get the clicker questions right or not, as long as they are participating.”

Angela, a lower-level undergraduate biology instructor

Faculty are satisfied with instructional practices

- Faculty were in general **satisfied** with their week of teaching.
- The most satisfying aspect was **student engagement**.
Faculty use weak evidence to assess their satisfaction

**Satisfaction with student engagement**
- Participation levels: 51%
- Students’ physical reactions: 34%
- Attendance: 15%

“Whenever I teach one of these big introductory courses, the students are quite engaged, people aren’t falling asleep and reading the [school newspaper] and so far they seem to be paying attention to me... You can look at the eyes of 150 students in a broad sweep, and if you just said something that doesn’t resonate or sink in, you get this kind of average glazed over look of the whole class... The students are engaged enough that I can tell from the way they are looking at me, just the eye contact that I’m making in this big lecture format, whether they are getting it or not, the people seem to be quite engaged.”

Clark, an experienced physics instructor

**Satisfaction with teaching**
- Personal feelings: 43%
- Student engagement: 36%
- Assessment results: 12%

“Quite satisfied. Yeah, I think I gave a pretty good lecture for each time and I think the class and I get along quite well, so I was quite pleased with it.”

“I was very satisfied... I mean, it can always be better, but with the amount of time I have, I think I use most of the tools that we have, like using the clicker, using the PowerPoint, using models to give students various ways to learn the same thing... I’m sure if someone else sees it, they might say this could be better, but I feel I’ve done my best.”
Faculty are not clear about student learning

- About a third of the faculty did not know whether their students had learned.
- Another third had some evidence but were also waiting on the results of summative assessments.
- None of them say that students did not learn, even if some evidence pointed to the contrary.

"I really won’t know until I give them the exam and at the exam time, I really don’t go back and see who was actually in attendance and did well on the exam..."

Dwight, an instructor of a lower-level biology course

Faculty have plans to revise their course

- Most faculty identified specific aspects of their teaching they would change:
  - 51% want to adjust content coverage

"I would probably emphasize more of the basic chemistry... The point is, if I'm talking about enzymes, they should understand the protein structure. If I'm talking about membranes, they should know what a phospholipid is. You can understand the materials by reviewing the background of chemistry. So I'd probably emphasize that a bit more."
Faculty have plans to revise their course

- Most faculty identified specific aspects of their teaching they would change:
  - 51% want to adjust content coverage
  - 73% want to change their approach to teaching

“I would probably skip the worksheet and give it to them as a homework. I felt that starting out with a worksheet was good in theory, they found it as hard as I hoped they would. I had hoped they would find it hard, but they found it really hard. So I probably would not have led in with that.”

The relationship between satisfaction and change is complex

- Research has suggested that dissatisfaction is necessary although not sufficient for instructor to engage in instructional change.


The relationship between satisfaction and change is complex

- Only satisfaction with teaching was significantly related to enrollment in pedagogical workshop.

<table>
<thead>
<tr>
<th>Satisfaction with teaching</th>
<th>Workshop enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did not enroll in either workshop</td>
<td>82</td>
</tr>
<tr>
<td>Enrolled in Peer Instruction</td>
<td>12</td>
</tr>
<tr>
<td>Enrolled in Just-in-Time Teaching</td>
<td>30</td>
</tr>
</tbody>
</table>


The relationship between satisfaction and change is complex

- None of the different types of satisfaction predicted instructional change.


Teaching experience was the only predictor of instructional change

- Teaching experience level was significantly related to change in course content ($p < 0.0013$) and course goals ($p < 0.0004$).

STEM faculty weakly embody Scientific Teaching

**Scientific Teaching**
- A scientific teacher evaluates learning regularly and makes teaching decisions based on evidence.
- Scientific teaching is an iterative process of review and revision.
- Active learning, assessment, and diversity are core themes of scientific teaching.

**STEM faculty**
- Many faculty evaluate learning a few times a semester.
- Teaching decisions are based on weak evidence (i.e., personal feelings and student physical responses).
- Junior faculty are more likely to plan for revisions.
- Faculty mostly employ teacher-centric strategies and summative assessment.

STEM faculty have limited educational knowledge

- STEM faculty’s instructional decisions are grounded in *content coverage* not students’ learning outcomes.

- STEM faculty have *limited knowledge of assessment* and their role in informing their own practices.

STEM faculty’s teaching mindset is teacher-centric

- Results point to a self-centered mindset with limited considerations of student learning.

- Faculty’s experiences as students and the environment at research-intensive institutions enforce this mindset.
Change strategies should focus on reflective practice

1. Create Learning Goals
   What should students know and be able to do after instruction?

2. Determine Evidence for Learning
   How will progress toward learning goals be gauged?

3. Planning Learning Experiences
   How will students be engaged in pursuit of the learning goals?

4. Evaluation, Review, and Revision
   What were the outcomes of the instruction? What could be done differently going forward?

- We should not assume that reflections take place.
Change strategies should target personal empiricism

We assume your students don’t learn so use this strategy.

These assessments suggest my students are not learning; what should I change?


DBER needs to diversify studies on STEM faculty

- We need to study faculty in the wild, outside a reform effort.

- We need to characterize faculty’s instructional decisions and value system.

- We need to identify how research-based analytical tools can promote reflections and actions.
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@MarilyneStains
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