Preventive and Explorative: Two Workplace Problem-Solving Cultures

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Introduction

The EMPOWER project looked at four 21st century skills (**teamwork, communication, problem-solving, and self-directed learning**) are valued and taught across STEM:

- We analyzed how **different industries viewed problem-solving** and compared their perspectives.
- In the initial stages of analysis, we noted **significant differences between how petrochemical processing and computer science** thought of problem-solving.
- These differences lead to the present research questions
  - **How were these problem-solving cultures different?**
  - **What contextual factors influenced these differences?**
- For the analysis, we adapted Maanen and Schein's definition of organizational culture to consist of the **values and ideologies, language and tools, and processes of an organization**.[1]
- An example of an organizational culture was **safety culture** ("an organization's values and behaviors – molded by its leaders and internalized by its members – that serve to make […] safety the overriding priority"). [2]

Methods

Interviews were conducted in four high-STEM metro regions → Interviews were transcribed → First pass: three a priori codes were applied: definition of problem, strategies for solving, and teaching

Text searches for prevention, fix, and troubleshooting were performed → Second pass: a priori codes and text searches were reviewed, creating Open/Initial Codes[3] → Of the 1870 initial codes, 452 were selected for their relevance to preventive and explorative problem-solving

Third pass: the 452 initial codes graphically sorted in draw.io software into categories related to problem-solving, teamwork, communication → The sorted codes were separated into the preventive-explorative dichotomy → Fourth pass: the preventive and explorative codes were sorted into emergent themes

	Student Focus Group	Faculty Interview	Industry Interview
Computing	22	29	7
Energy	14	18	7
Health Care	9	12	3
Manufacturing	24	32	9

Code	# references
Definition of Problem	1010
Strategies for Solving	1257
Teaching	1390

Text searches	# results
prevention	516
Fix	136
troubleshooting	123

Preventive Problem-Solving Culture

has a desired state to preserve and will focus efforts on maintaining that norm, as extreme variance can lead to catastrophe

"*We are running an **incredibly complex amalgamation of machines and instrumentation***" –Petrochemical Faculty

Risk

Complexity

Uncertainty

"***Not every single one of those [wells] is going to be the exact same**. […] One might run for three years; one might run three days*" –Petrochemical Student

"*I continued to trace on the wrong pipe, I traced it in one valve, and I went and opened that valve and **it was the wrong valve**. […] because had that been on another line, that **could've meant an explosion**. It **could've meant equipment damage**. It could've meant a release that could've been very, very costly **whether it was equipment, whether it was injuries, whether it was fatalities***"–Petrochemical Faculty

"*The patient comes to us with a problem. They wouldn't need us if they didn't have a problem. And they can't say, 'Hey, I've got blood filling up in my pleural cavity and now I can't breathe.' **They just come in there and they can't breathe and they're not talking to you because they're focusing on that they can't breathe***." –Nursing Student

Safety

Team wide commitment
"*It's not just one nurse trying to save this person's life, **it's a whole team** of people who are called in*" –Nursing Student

Necessity of safety
"*Fundamentally, people from the outside would **view our job as operating these units to modify a chemical precisely** into something a customer would buy. And we do do that job all period on our 12-hour shift every time we come in. I guess fundamentally, that's our job, **but at the same time, we're responsible for the safety of everyone entering that unit** to perform all the ancillary work that has to be done to keep that unit running*" –Petrochemical Faculty

Analysis

Problem identification
*"You're looking at your board, and all of a sudden, **your pump starts reading high**. […] Okay, well, if you can't see past, okay, a hot pump and see okay, **am I getting flow to it**, **when was the last time this pump was maintained?** […] Okay, why is it reading high**? Is my flow out the tank not working? Is my PSV not cooperating?**"* - Petrochemical Faculty

Big data analysis
*"We are looking for problems before they exist by extrapolating the probability they will occur out of this **tremendous amount of data** that you saw on those screens"* – Petrochemical Faculty

Preventive Communication

Repeat-back technique
*"**Hey, I need you to go out and open a particular valve**,' then you, as a outside operator, you say, '**Okay, you just asked me to open FC10**,' and then I communicate back and say, '**Yes, you need to open FC10 one round**.' And then the outside operator says, '**Okay, I'm opening FC10 one round**.'*–Petrochemical Faculty

Nonverbal Communication
*"they could say "No, it doesn't hurt" or this or that. But if their facial-- they have facial grimacing or they're having signs and symptoms of pain, **we have to look at all forms of communication, not just verbal***" – Nursing Student

Explorative Problem-Solving Culture

encourages multiple creative solutions & iterative testing, often without worry about failure

Low Risk and Low Cost → Iteration & Creativity

Acceptability of failure → Generation of Many Solutions → Test, break, and critique → Generation of Many Solutions

"*Engineers have to be skeptical [...] We're being taught that as engineers, failure is our job. Make things break*." -Manufacturing Student

"*It takes 10 ideas to come up with a good one. It takes 100 ideas to come up with a great one. It takes 1,000 ideas to come up with a ground-breaking one*" -Optical Engineer

"*10% of your time writing that program and 90% bug fixing*" -Computer Science Student

"*I've been programming for five years and never once have I written a program that has worked on the first try. It just hasn't happened*" -Computer Science Student

Accepting Failure

"*You have to have **the right cultural conditions where it's okay to highlight imperfection**. […]There's a glass half full notion of even the idea of having problems. And maybe even **reframing problems as opportunities**, and sometimes it sounds cliché but it's a problem or an opportunity*" –Computer Scientist

Breaking and Fixing in IT

"*A lot of times, when you're dealing with an issue, particularly in the IT side, you're probably dealing with someone that's not very technical trying to convey technical information. So **you kind of have to weed through what they're telling you**, kind of get the information that you need, and then be able to go and look and be like, 'Okay. So this is what we're seeing now. How do we start solving this problem?'*" –Information Technologies Student

Disposability

"*You're working on troubleshooting circuit boards to try to figure out what's wrong. […]And the board better be worth it to pay somebody per hour to inspect and fix that circuit board. So that's a lower end. A lot of companies just choose now **just to throw the board out and just put a whole new board in. It's just cheaper, faster** to do it that way*" –Manufacturing Faculty

Mid-Process Optimization

"*If you're speeds and feeds are wrong, you're going to have chatter. **Well to adjust chatter, it's going to be on the fly**. You're not going to be able--obviously, if something's break, hit feed hold and stop the machine or the emergency stop. But there are overrides where you can say spin higher or feed rate higher or slower, depending on what is needed*." –Mechanical Engineering Student

Conclusions

- Major contributors to the type of problem-solving an organization attempted were the **potential for risk** involves, the **cost** of the procedures, and the **implications of failure**.
- Cost was a significant motivator behind the petrochemical processing industry, which lead to the **balancing between continuous operation and safety**
- The problems solved across all of the industries examined were complex and largely dependent on the greater context and affected their views of what problems were
  - **A preventive culture**
    - **was constrained** by staying within a bounded state (e.g., keeping the plant running)
    - involved diagnosing a variance from the desired state
    - applied a preplanned solution process to return to a **predetermined end goal, maintaining the state**
  - **An explorative culture**
    - had a general direction, but a **less specific and malleable end goal**
    - involved **flexible solution paths** to find the best way to reach the goal
- **Limitation:** Preventive and explorative are not the only two problem-solving cultures, and their strategies are not mutually exclusive, but the overall organizational approaches were consistent across the industries analyzed.

Where does Physics Fit?

- Physics is not an industry, it is an academic discipline, which does not specifically fit into a preventive or explorative problem-solving culture.
- Physicists have skills that could let them fit into an organization with either of the problem-solving culture

Educational Implications

- Neither preventive or exploratory problem-solving are particularly prevalent in undergraduate physics education
- An undergraduate research lab can provide learning opportunities that emphasize safety and structured procedures, which are typical in a preventive culture.
- Computational physics and electronics lab courses could be good places to introduce students to explorative cultures where they can quickly try new things with relatively low risk and learn from failure.

References

[1] J.V. Maanen and E.H. Schein, Towards a theory of organizational socialization (1979).
[2] Principles for a Strong Nuclear Safety Culture, Tech. Rep. (Institute of Nuclear Power Operations, 2004).
[3] J. Saldana, *The Coding Manual for Qualitative Researchers*, second edition ed. (SAGE Publications Ltd, Los Angeles, 2012).

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