The Role of Affect in Science Literacy for All: Policy Implications

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Grand Challenges

Main References

Fortus, D., Lin, J., Neumann, K., & Sadler, T. D. ₵022). *The role of affect in science literacy for all*. International Journal of Science Education, 44(4), 535-555. https://doi.org/10.1080/09500693.2022.2036384

Sadler, T. D., Zhen, X., & Fortus, D. (submitted).*Restructuring the Science Curriculum around Grand Challenges*. International Journal of Science Education

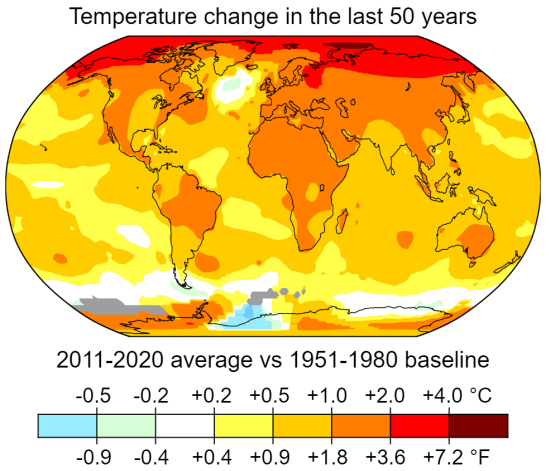
Project Goals

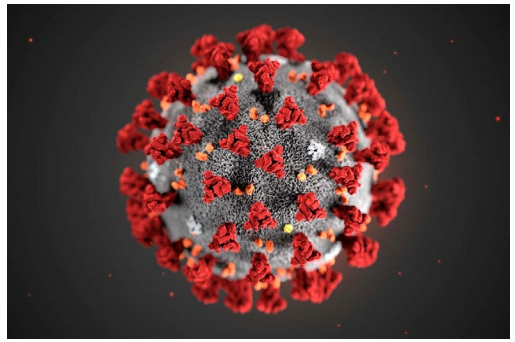
1. The project is the 1st stage in a long-term vision, funded by NSF, aiming to restructure MS science education around the GCs
2. The goal is to develop ***informed agency*** = *affect + knowledge*
3. Affect = self-efficacy + mastery orientation + positive attitudes
4. I now explain the rationale underlying the project's affective aims and their implications for education policy

What are the Grand Challenges (GCs)?

The GCs are global socio-scientific issues that have varying local implications. They are issues that are shaping our lives and will continue to do so for the next decades.

- Climate change
- Personalized medicine
- Pandemics
- Availability of fresh water
- Clean energy sources
- Plastic pollution
- Ecosystem destruction
- Genetic engineering
- Antibiotic resistance.....





Why Everybody Should Learn Science

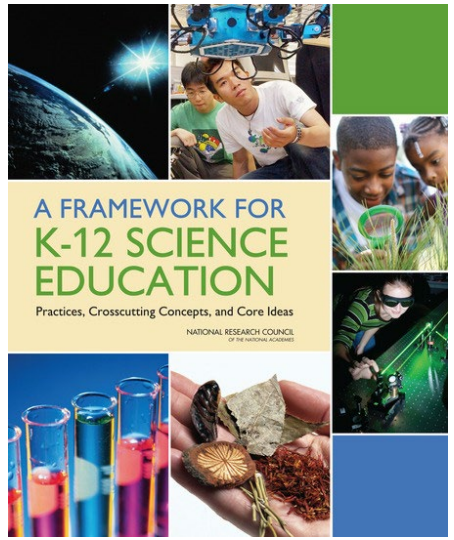
Five arguments why everybody should learn science:

1. The economic argument
2. The utilitarian argument
3. The democratic argument
4. The social argument
5. The cultural argument

Millar, R. (1996). Towards a science curriculum for public understanding. *School Science Review, 77*(280), 7-18.

Why Everybody Should Learn Science

"The overarching goal of our framework for K-12 science education is to ensure that by the end of 12th grade, all students have some appreciation of the beauty and wonder of science [a cultural argument]; possess sufficient knowledge of science and engineering to engage in public discussions on related issues [a democratic argument]; are careful consumers of scientific and technological information related to their everyday lives [a utility argument]; are able to continue to learn about science outside school [a lifelong learning argument]; and have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering, and technology [an economic argument]." (p.1)

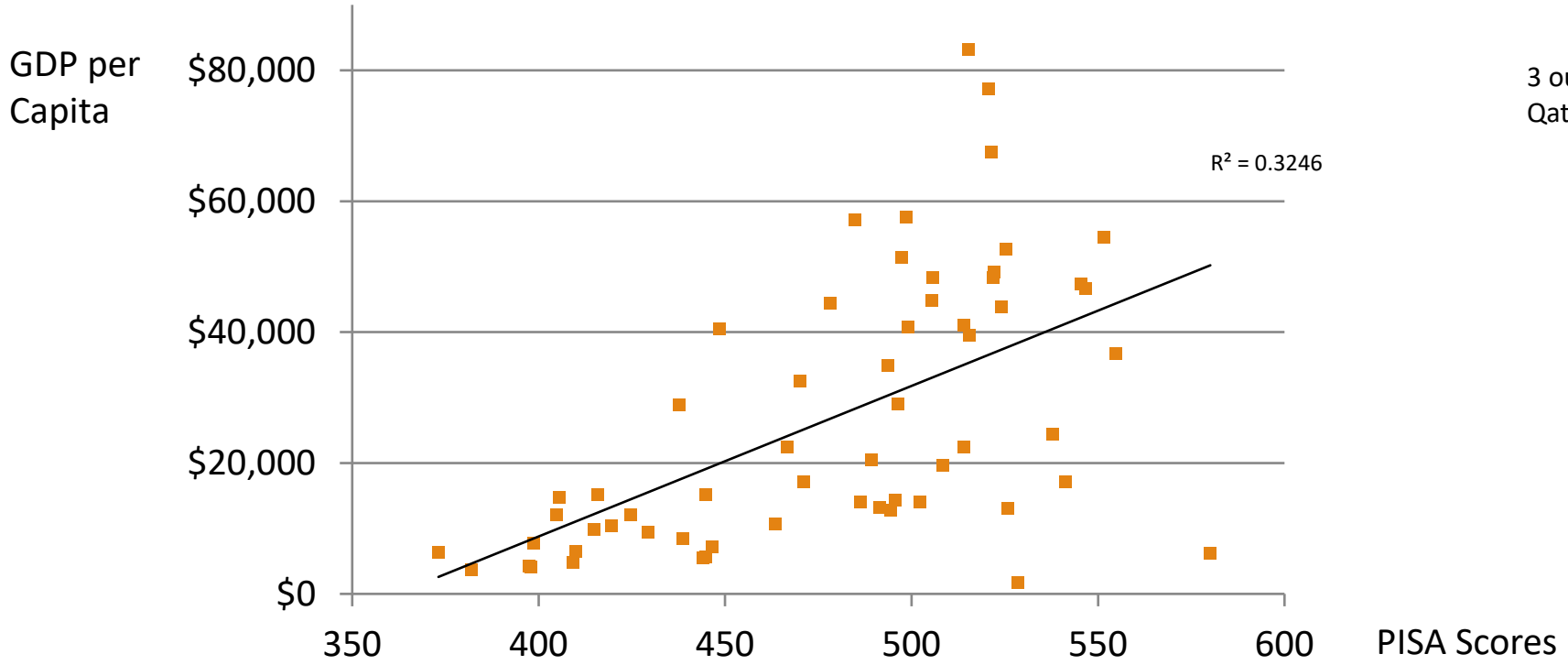


National Research Council (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC, National Academies Press.

The Economic Argument

"There is a connection between the level of public understanding of science and the nation's economic wealth. In addition, scientific and technical achievement is seen as a sign of a nation's international standing. Maintaining this depends on a steady supply of technically and scientifically qualified personnel." (Millar, 1996, p. 9)

GDP per Capita vs. Science PISA Scores for 2012



3 outliers were removed - Qatar, Norway & Lichtenstein

Knowledge of science → National economic wealth

or

Knowledge of science ← National economic wealth

?

Economic Growth

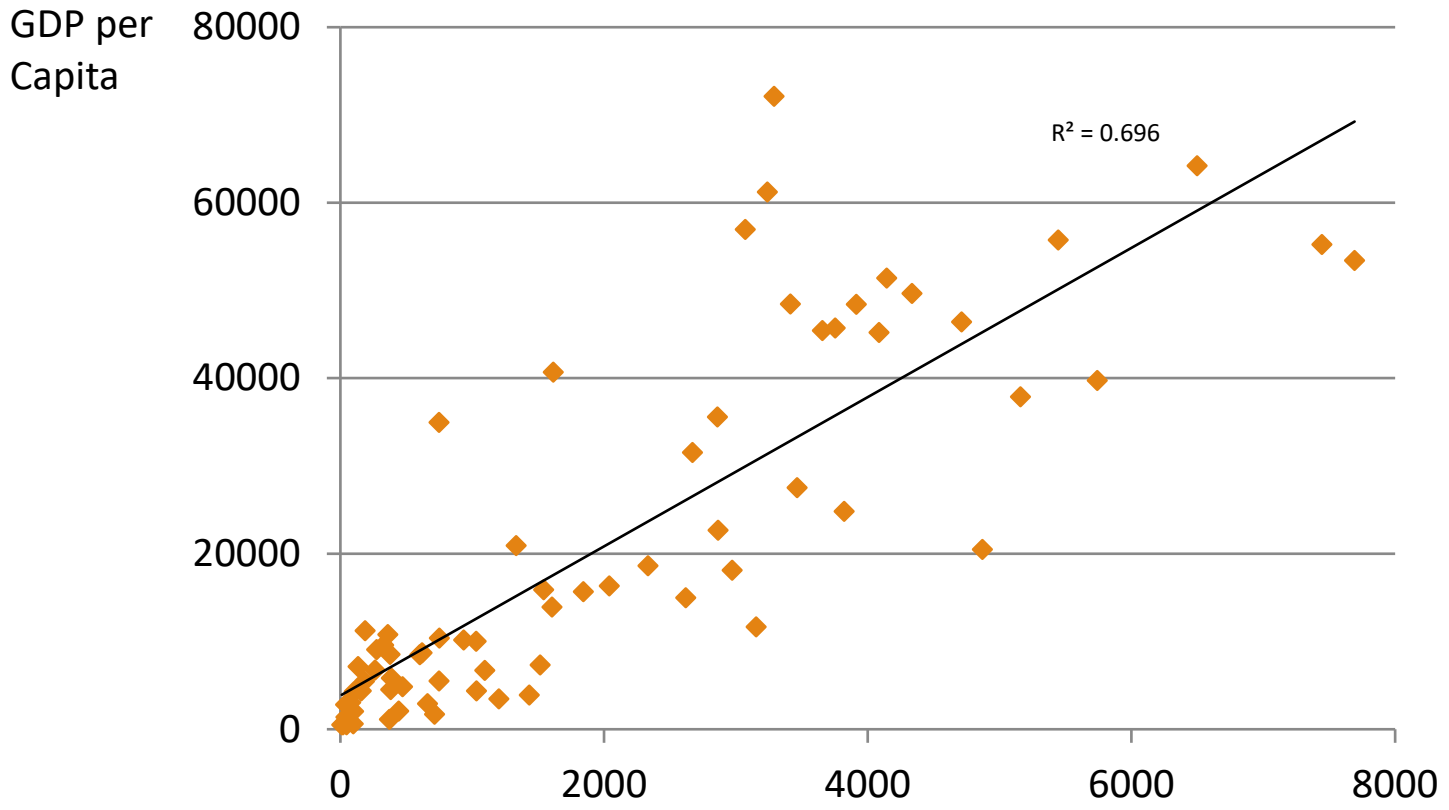
When controlling for countries' initial GDP per capita:

i. Scores in large-scale assessments proportional to average annual growth

ii. A 10% increase in all students' mathematics and science literacy scores predicted an increase in annual GDP growth by .3%, while a 10% increase in the scores of top-performing students predicted an annual 1.3% GDP growth

Hanushek, E. A., & Wössmann, L. (2015). The knowledge capital of nations. MIT press.

GDP per Capita vs. Number of Scientists & Engineers per Million People



3 outliers were removed - Qatar, Norway & Lichtenstein

The Economic Argument

The prior graph and Hanushek & Wössmann's argument seem to indicate that the economic goal of science education is:

To increase the number of future scientists & engineers

Is it important to continue teaching science to ALL, even if the chose/after they have chosen not to major in science?

The Economic Argument
Conclusion

What predicts continuing into a STEM profession?

a. Grades in science - NO

b. Self-efficacy & enjoyment of science studies - YES

Taskinen, P. H., Asseburg, R., & Walter, O. (2009). Who would like to chose natural science related or technical profession? Skills, self concept and motivation as predictors of professional expectations in PISA 2006. In: Prenzel, M., Baumert, J. (eds). *Vertiefende Analysen zu PISA 2006*. VS Verlag für Sozialwissenschaften. https://doi.org/10.1007/978-3-531-91815-0_5.

Taskinen, P. H., Schütte, K., & Prenzel, M. (2013). Adolescents' motivation to select an academic science-related career: the role of school factors, individual interest, and science self-concept. *Educational Research and Evaluation, 19*(8), 717-733.

Conclusion: The economic goal of science education is:

a. To enhance students' self-efficacy and enjoyment of science studies, thereby increasing the number of students who chose science-related professions.

b. Improve the knowledge of science of the top scorers

Any Quick Questions?

The Utilitarian Argument

"An understanding of science and technology is practically useful, especially to anyone living in a scientifically and technologically sophisticated society. They are better equipped to make decisions about diet, health, safety, and so on, to evaluate manufacturers' claims and make sensible consumer choices." (Millar, 1996, p. 9)

The Utilitarian Argument

I will address this argument in two ways:

1. The way in which digital technologies have influence the need for science knowledge to navigate life in the 21st century
2. The role of knowledge in decision making

The Utilitarian Argument
The Role of Digital Technologies

1. Modern apparatuses are design to be black-boxes, not to require any special knowledge, to be idiot-proof. This wasn't always so:
   a. Cars
   b. Record players
   c. Radios
2. Modern digital technologies minimize the range of situations in which science knowledge could have been relevant

Chapman, B. (1991). The overselling of science education in the eighties. *School Science Review, 72(260), 47-63.*

The Utilitarian Argument
The Role of Digital Technologies

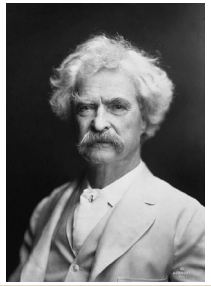
1. Even many STEM professionals, such as technicians and mechanics, barely need any scientific knowledge.
2. Diagnostic programs: technicians know how to operate the diagnostic programs and replace parts.
1. They use practical knowledge, not scientific knowledge
2. The designers of new technologies need scientific knowledge – still.
5. Can physicists repair their cars or even know what is wrong with them?
6. There is a gap between theoretical knowledge and the ability to make existential changes

The Utilitarian Argument
The Gap between Knowledge and Behavior

1. The livestock sector is globally "one of the largest sources of greenhouse gases and one of the leading causal factors in the loss of biodiversity, while in developed and emerging countries it is perhaps the leading source of water pollution." Food and Agriculture Organization [FAO] of the United Nations. (2006). *Livestock's long shadow: Environmental issues and options*. p. 267.

2. "Appropriately planned vegetarian diets, including total vegetarian or vegan diets, are healthful, nutritionally adequate, and may provide health benefits in the prevention and treatment of certain disease."

   American Dietetic Association. (2009). Position of the American Dietetic Association: Vegetarian Diets. *Journal of the American Dietetic Association, 109*(7), 1266-1282.



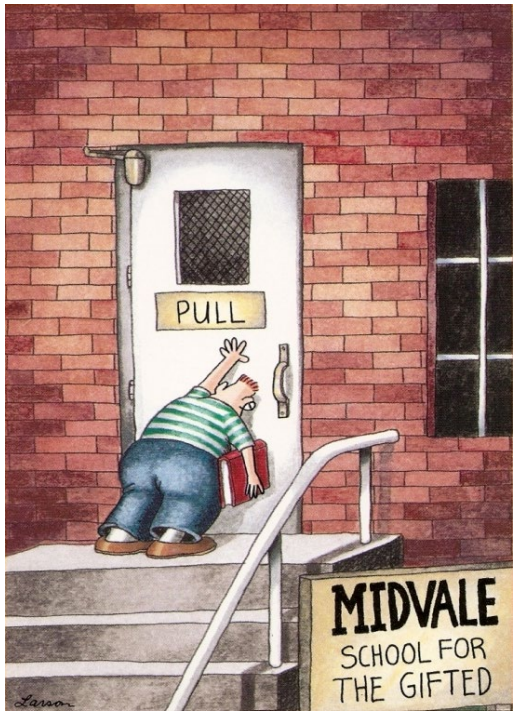
3. Rephrasing Mark Twain: "A person who doesn't read has no advantage over a person who can't read."

The Utilitarian Argument
The Gap between Knowledge and Behavior

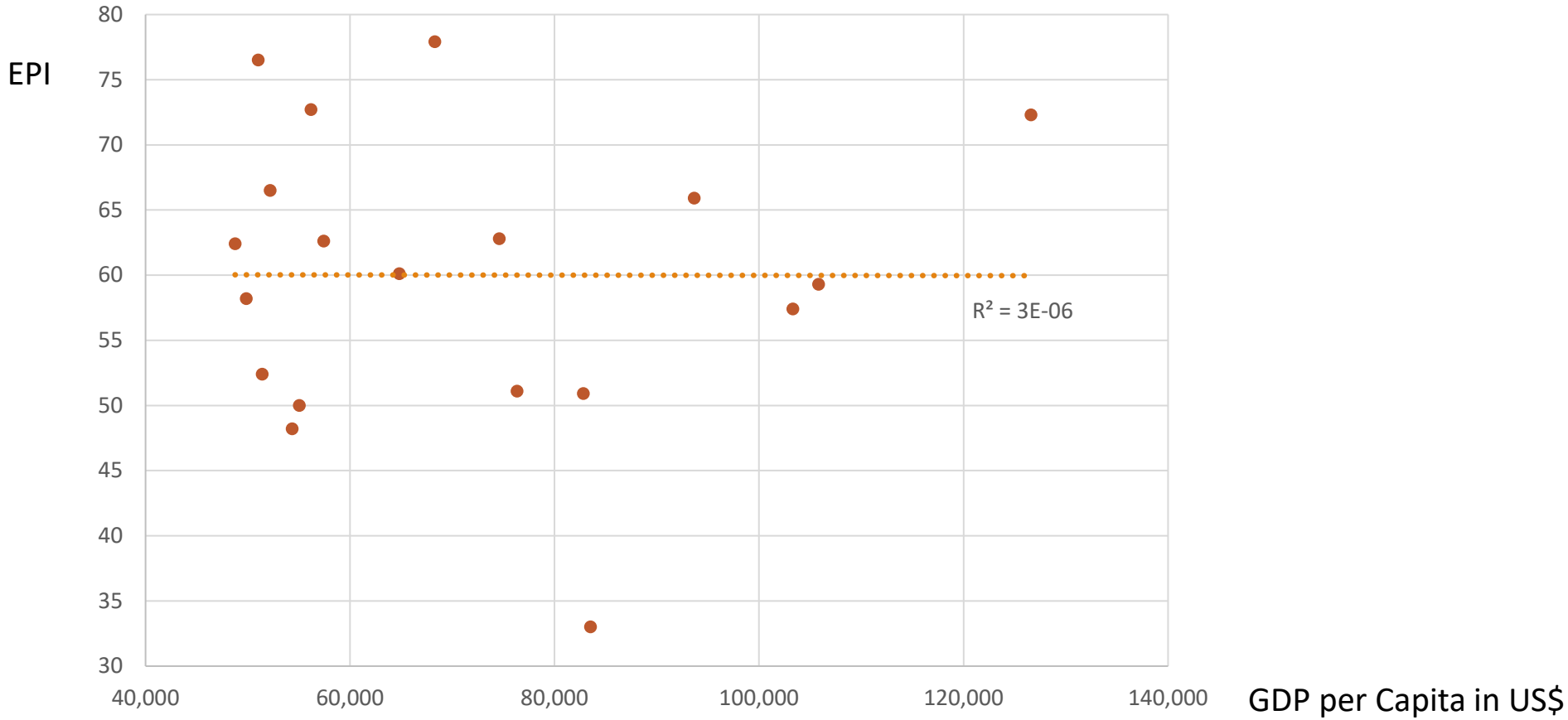
1. In many areas of life, we are more instinctive creatures than rational ones
    a. People eat meat, drive big cars and do other “unwise” things because these behaviors bring the pleasure
    b. People often don’t behave “wisely” because they involve too much effort or cost.

The Utilitarian Argument

1. Of course, our knowledge influences our behavior!!!
2. It's just that its influence is often smaller than we would like to believe
3. We should be modest when using the utilitarian argument to justify science literacy for all



Environmental Performance Index vs. GDP per Capita (2022)



The Utilitarian Argument

For people to use their scientific knowledge in decision making, the knowledge needs to be detailed and specific to the situation under consideration, and people need to be aware they have knowledge that is relevant to the situation.

For example, when considering whether to get vaccinated, one needs understand:

a. The characteristics of the pathogen and the disease it causes
b. How the disease can be treated
c. The odds of being exposed to the pathogen
d. How the vaccination works
e. Issues related to weakened immune systems
f. The risks involved in being vaccinated
g. The schedule in which the vaccine is given
h. And more…

Most of this will not be taught in school and changes all the time

The Utilitarian Argument

Another example, whether to purchase an electric car or a turbo-charged diesel car:

a. Whether the source of electricity is renewable (what is a renewable source?)
b. The efficiency of transferring energy from a source to the car's wheels
c. The contamination caused the car's battery in comparison to greenhouse gas emissions
d. The average life of a battery compared to an engine
e. Charging opportunities (depends on where you live and drive)
f. And more…

Most of this will not be taught in school and changes all the time

The Utilitarian Argument
Lifelong Learning

1. To increase the odds that people will use their scientific knowledge in decision making, they need to be lifelong learners
2. This is reminiscent of PFL, where the quality of learning is determined by the preparation it provides for future learning
   Bransford, J. D., & Schwartz, D. L. (1999). Rethinking transfer: A simple proposal with multiple implications. *Review of Research in Education, 24*, 61-100.
3. The odds that people will learn new things required to make decisions increases as they become more mastery-oriented
   Belenky, D. M., & Nokes-Malach, T. J. (2012). Motivation and transfer: The role of mastery-approach goals in preparation for future learning. *Journal of the Learning Sciences, 21*(3), 399-432.
4. The odds that people will learn new things required to reach justifiable decisions increases as their self-efficacy increases

The Utilitarian Argument
Conclusion

I believe that:

1. We should be modest about our expectations regarding the utilitarian value of science literacy
2. To enhance the utilitarian value of science education for all, we need to focus not only on knowledge and skills, but also on students' tendency to be mastery oriented towards science and self-efficacious.

Just a moment to drink some water…

The Democratic Argument

"An understanding of science is necessary if any individual is to participate in discussion, debate and decision-making about issues which have a scientific component. Decisions have to be made about transport, energy policy, testing of drugs and treatments, disposal of wastes, and so on. There should be public accountability about the directions of some scientific research, and public involvement in decisions about whether or not to apply such knowledge." (Millar, 1996, p. 9)

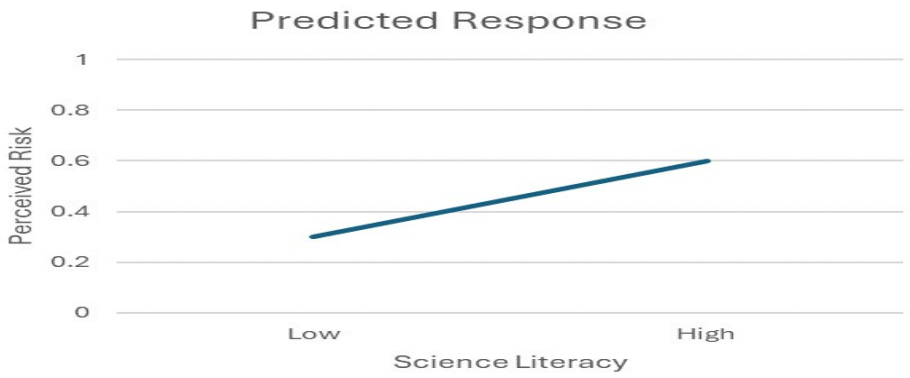
The Democratic Argument

Citizens have the right to participate in discussions, debates and decision-making about scientific issues made locally and nationally, regardless of their understanding of the topic or their socio-cultural beliefs. This often leads to behaviors and support of policies that run contrary to accepted scientific knowledge.

Scientific American Board of Editors. (2017, February). A letter to Washington. *Scientific American,* 7.

“For ordinary citizens, the reward for acquiring greater scientific knowledge and more reliable technical-reasoning capacities is a greater facility to… explain away evidence relating to their [peer] groups’ positions.”

Kahan, D. M., Peters, E., Wittlin, M., Slovic, P., Ouellette, L. L., Braman, D., & Mandel, G. (2012). The polarizing impact of science literacy and numeracy on perceived climate change risks. *Nature climate change, 2*(10), 732-735.



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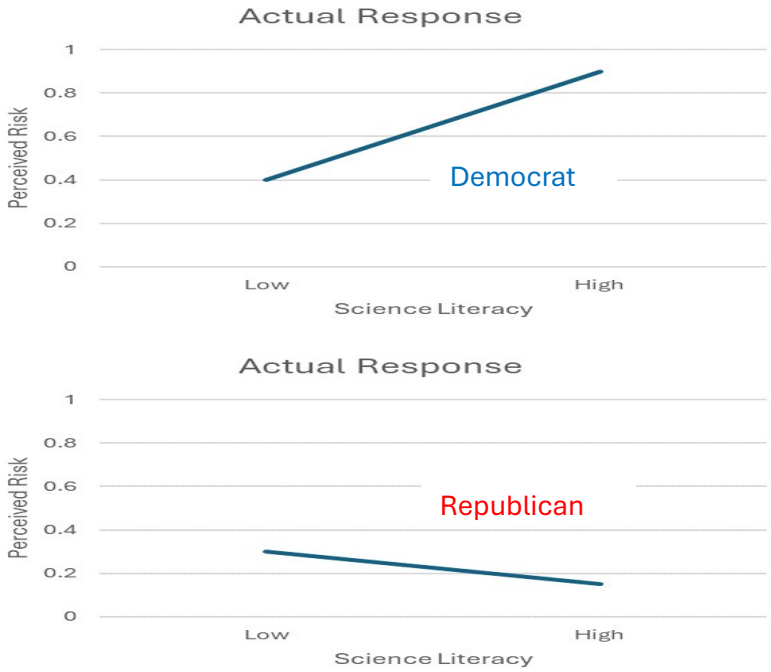


The Democratic Argument

1. Assuming that we aren't trying to promote particular positions regarding socio-scientific issues (is that true?), we need ask:
   a. Can science knowledge compete with ideological leaning?
   b. If yes, what level and what kind of science knowledge is required to be able to truly understand and influence, not just accept the position of a favorite politician?
   c. Can this level of science knowledge be reached in K-12 education?

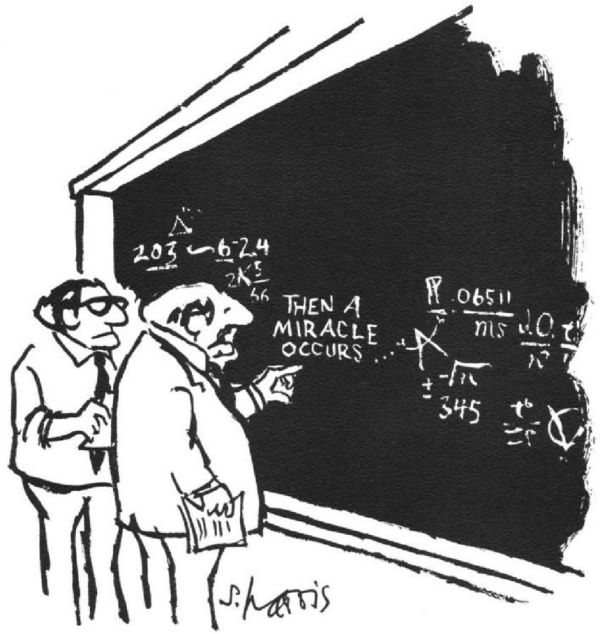
2. This brings us back to lifelong learning (mastery orientation and self-efficacy)

The Democratic Argument

1. Studies have shown that knowledge ***about*** science, rather than knowledge ***of*** science, are of greater utility in the public domain

Of special utility was understanding how science claims are constructed and justified

Ryder, J. (2001). Identifying science understanding for functional scientific literacy. *Studies in Science Education, 36(1), 1-44.*



The Democratic Argument
Conclusion

I believe that:

1. To enhance the democratic value of science education for all, we need to focus on students' tendency to be mastery oriented and self-efficacious.
2. We need to emphasize knowledge *about* science

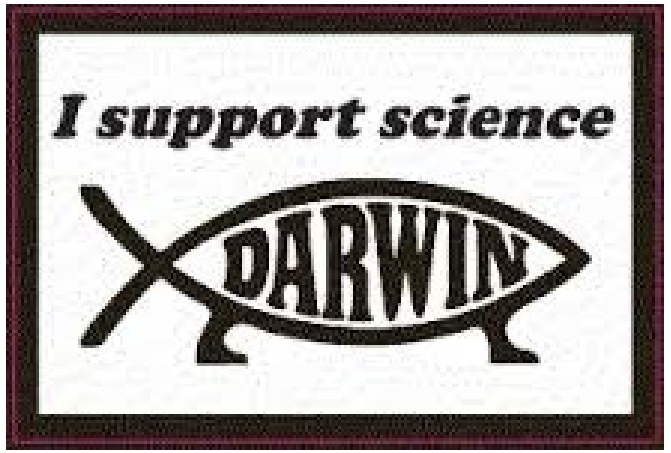
The Social Argument

"It is important to maintain links between science and the wider culture. Specialization and the increasingly technical nature of modern science is seen as a social problem, leading to incipient fragmentation – and the alienation of much of the public from science and technology. A related argument is advanced from the science side: that improved public understanding will lead to more sympathy with, and hence greater support for, science and technology itself." (Millar, 1996, p. 9)

The Social Argument

This argument deals with the need to develop and strengthen positive attitudes towards the scientific enterprise, not with the need to develop scientific knowledge and skills.

Can people hold positive attitudes towards science without strong scientific knowledge?

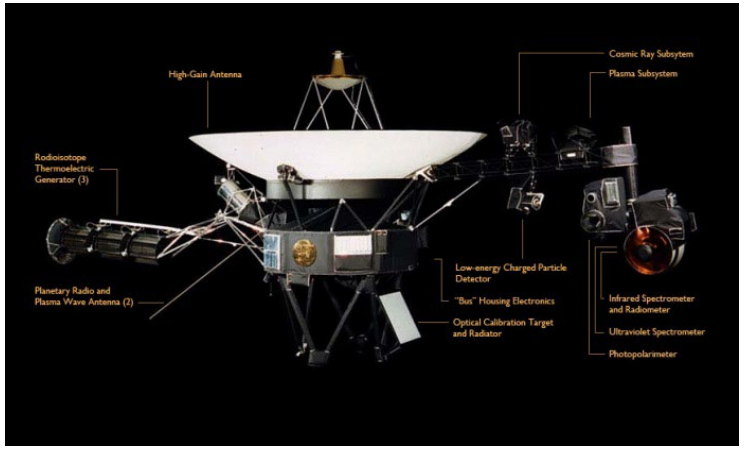


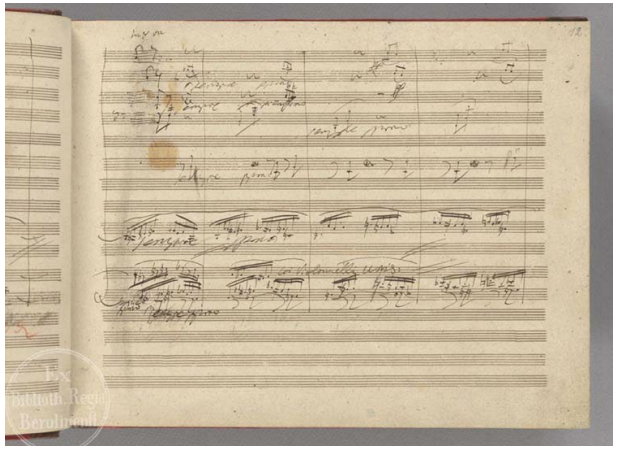
The Cultural Argument

"Science is a major, indeed, the major achievement of our culture and that all young people should be enabled to understand and to appreciate it. We should celebrate science as a cultural product." (Millar, 1996, p. 9)

The Cultural Argument

1. This argument is true for art, music, and drama as well
2. Do we expect all citizens to be dramatically literate?
3. Like the social argument, the cultural argument is about attitudes, not knowledge





Summary

1. Economic Argument
   a. Teach science in a way that enhances enjoyment, interest and self-efficacy, in order to maximize those that will choose to major in science
   b. Promoting understanding is more important for top-achievers than for all the others
2. Utilitarian Argument
   a. Teach to enhance mastery orientation and self-efficacy for autodidacticism
3. Democratic Argument
   a. Teach the epistemology of science
   b. Teach to enhance mastery orientation and self-efficacy for autodidacticism
4. Societal & Cultural Arguments
   a. Teach to develop positive attitudes

Bottom Line

1. All the standards documents with which I am familiar ignore these conclusions
2. Many studies have shown that students, mastery orientation, attitudes, and self-efficacy decline between 3rd and 9th grades
3. What would a pedagogy that takes these issue into account look like?
4. That is one of the goals of the ***Grand Challenges*** project

Thank you!!