When are pedagogically motivated simplifications dangerous lies?

Mattias Alveteg

***Abstract*—Conspiracy theories, labelling unwanted facts as "fake news", and coming up with your own alternative facts are trends that seem to have exploded in recent years. As academically trained individuals we might shake our heads at the folly of the general public, but perhaps we are, at least partially, to blame through the way we teach our students. Textbooks in various disciplines are full of oversimplifications that are presented as truths without any indication that reality is more complex than that. Is there a way we can change our pedagogics such that we help our students, and the general public, to overcome the Dunning-Kruger effect?s**

***Index Terms*—lies-to-children, learning thresholds, Dunning-Kruger effect, Zone of Proximal Development, ignorance**

I. Lies-to-children and the Dunning-Kruger Effect

MY daughter once asked me to help her with this math homework task she really struggled with:

"*Peters' bathtub takes 4 minutes to fill and 8 minutes to empty. How long time does it take to fill the bathtub if the bottom plug is removed?*"

Since this was a math book for fifth grade pupils, the author's intentions were clear to me: Assume that the inflow and outflow rates are constant and deduct one from the other to calculate the answer. However, that is not how bathtubs and other water reservoirs work: The outflow rate is dependent on the height of the water level. The author thus created a potential conflict. Anyone testing the task e.g. in their kitchen sink, may either draw the conclusion that math has nothing to do with reality or that the assumption used in the textbook is nonsensical. As shown in the next section, similar conflicts are created by university level textbooks.

Simplification and motivation *are* central in teaching. There are obstacles, learning thresholds [1], in our different disciplines that are difficult for our students to overcome. When approaching these obstacles, the student might get de-motivated if the learning situation we expose them to creates too much cognitive dissonance, too much conflict with their current understanding. There seems to be a zone of proximal development [2], a maximal possible distance between the students' current understanding and the leap in understanding we can achieve. If we aim outside the zone of proximal development, the student will likely either be entirely de-motivated to learn or find the learning situation impossible to benefit from. It would e.g., likely be futile to try to teach a child how relative velocities are calculated in general relativity and thus while teaching them basic physics we pretend that velocities can simply be added and subtracted.

The mathematician Ian Stewart and the biologist Jack Cohen coined the phrase *"lies-to-children"* [3], [4] to describe how we, in our efforts to facilitate learning, tell our students gross simplifications as if they were entirely true. Perhaps our lies-to-children would be harmless if we lived in a world where scientists were seen as authorities in matters relating to their discipline and where the general public fully trusted statements made by scientists. However, studies in e.g., the U.S. [5] indicates that the relation between the general public and the scientific community is way more complicated than that.

To some extent, the complicated relation between the scientific community and the general public and indeed between different parts of the scientific community might be explained by **the Dunning-Kruger effect** (DKE) [6], [7]. The cause and magnitude of the DKE have been the center of an intense scientific debate [7], [8], [9] but to simplify, the DKE is the observation that individuals with little knowledge or ability within a topic tend to overestimate their knowledge and ability: We tend to be ignorant of the nature and extent of our own ignorance.

The DKE might perhaps be an explanation why we recently have seen e.g.

1) Private individuals who put more trust in random postings in social media than recommendations regarding the Covid-19 pandemic from experts in disease control.
2) Scientists and others, with some knowledge in statistics, "proving" that there was massive election fraud in the 2020 US elections [10], [11], [12].
3) A flurry of YouTube-videos from flat-earth believers making incredible (pun intended) use of various observations and scientific theories.

Is there a way we can "vaccinate" our students against the DKE making them at least slightly more aware of their own ignorance?

II. Lies-To-Children impact university education

A. Reaction rates

We all have our favorite things to complain about and I "inherited" mine from my former colleague Nils-Åke Danielsson (*1940 †2020), namely how reaction rates are "defined" in chemistry textbooks. Recently I went through *all* general chemistry textbooks physically available at the Kemicentrum library at Lund University and found only *one* textbook with a correct definition, all others were either

Manuscript received November 8, 2021.

M. Alveteg, is with the Department of Chemical Engineering and the Department of Food Technology, Engineering and Nutrition, both at Lund University, P.O. Box 124, 221 00 Lund, Sweden (e-mail: mattias.alveteg@chemeng.lth.se).

misleading or completely wrong. The second-best textbook [13] from this perspective had two interesting statements on subsequent pages, and I paraphrase

1) Since the methane concentration in the atmosphere essentially remains constant over time, the reaction rate for the breakdown of methane is thus approximately equal to the rate by which methane is released to the atmosphere.
2) Reaction rate is defined as the time derivative of concentration

I hope you see the conflict here. If the second statement is true, the reaction rate for the breakdown of methane is zero since the concentration is constant. The second statement is indeed incorrect and creates nonsensical results for all but one very special case[1].

B. *Energy is indestructible*

I believed this to be an absolute truth, except when mass is converted to energy or vice versa, until about a year ago. I did know that the microwave background radiation has a radiation "temperature" of a few Kelvin but still did not see the contradiction: If energy was indestructible, the photons from the tremendously hot Big Bang would have a very *high* radiation "temperature". It wasn't until I stumbled upon a YouTube video [14] that I understood that there *was* a contradiction and that this contradiction is resolved by the fact that photons can lose energy through the expansion of the universe, a process called *cosmological redshift*.

On a somewhat similar note: A decade ago my colleagues at the department of chemical engineering often voiced their frustration over students (and teachers from other departments) using the incorrect terms "*energy production*" and "*energy consumption*". Energy cannot be produced or consumed, it can only be transformed into different forms, so the scientifically correct terms are "*energy supply*" and "*energy use*". On the other hand, they did say "*my jacket is warm*" even when the temperature of their jacket wasn't high, the scientifically correct phrase being: *"My jacket is* a *good heat insulator"*.

C. *Physicists are searching for the theory of everything*

Although a good PR-stunt, this phrase lends itself to dangerous misconceptions about science. We do not expect the grand unification theory to explain, e.g., the (a)social behavior of cats, and thus it will *never* be a theory of *everything*.

A, from my perspective, similar quote was once voiced by the then University Chancellor of the Higher Education Agency (HSV) in Sweden, and I paraphrase[2] *"All problems that humanity has ever faced were solved by engineers and this will remain true."* [15]. I find these two quotes similar as they reveal an ignorance the societal impact of other fields of science and that they communicate that other perspectives on human life (e.g. love, trust, and belonging) are unimportant.

D. *The Larch (and other "trees")*

Like me you probably once were taught to recognize different tree species, like larch, oak, birch, fir etc., but what is a tree? As it turns out it is far from trivial to define what a tree is [16]. Woody growth and tree-like growth has developed by evolution multiple times over the millennia and the distinction between herbs and trees isn't as obvious as at least I was led to believe.

III. What to do? "Vaccination" against DKE?

I do not argue that we should abolish all attempts to simplify subject content and I do understand that simplified messages are crucial in e.g., building the political momentum needed to fund education and research. However, I am convinced that we as scientists and teachers at the university level have an obligation to critically evaluate both how we teach and what we teach. Identifying and analyzing the simplifications we use and the effect they have on our students and their learning is, in my opinion, an important part of the responsibilities of a university teacher. Above I have listed a few examples of simplifications, of lies-to-children. I am probably still ignorant of plenty of simplifications I have used and still are using in my own teaching and **would like to see discussions between colleagues on what simplifications are necessary, detrimental, unhelpful etc. I would also like to see discussions regarding methods to communicate to our students that we do use simplifications, that what we teach them is only partially true.**

In my own teaching material, I try to include footnotes, comments and similar where I give hints regarding the limitations of the simplifications I use. Not surprisingly some students are frustrated by these "*Our reality is more complicated than this theory*" comments. On the other hand, I do believe Charlotte Silén is correct in her argument that frustration is an integral part of the learning process [17] and I would hypothesize that **repeatedly pointing out to our students the simplifications we use** and thereby trying to make them aware of the nature of their own ignorance, currently is the best "vaccine" we have against the Dunning-Kruger effect.

[1] For a **single irreversible reaction** in a **closed** system with **constant volume** the time derivative of concentration *equals* the reaction rate.

[2] Original quote in Swedish: "*Alla problem som mänskligheten ställts inför har lösts av ingenjörer sedan tidernas begynnelse och så kommer det att förbli*"

References?

[1] J. H. F. Meyer, and R. Land, "Threshold Concepts and Troublesome Knowledge 1 – Linkages to Ways of Thinking and Practising. in Improving Student Learning – Ten Years On. C.Rust (Ed), OCSLD, Oxford 2003

[2] B. Eun, "The zone of proximal development as an overarching concept: A framework for synthesizing Vygotsky's theories" *Educational Philosophy and Theory,* vol. 51(1), pp 18-30, 2018 https://doi.org/10.1080/00131857.2017.1421941

[3] T. Pratchett, I. Stewart, and J. Cohen "The Science of Discworld" Ebury Press, ISBN 978-0091865153, 1999

[4] A. Sawyer "'Narrativum' and 'Palatable Instruction' in 'The Science of Discworld'" *Journal of the fantastic in the arts, vol 13(1), pp. 62-81, 2002*

[5] G. Gauchat, "The cultural authority of science: Public trust and acceptance of organized science" *Public. Understand. Sci.,* vol. 20(6), pp. 751-770, 2011

[6] J. Kruger, and D. Dunning, "Unskilled and Unaware of It: How Difficulties in Recognizing One's Own Incompetence Lead to Inflated Self-Assessments" *Jorunal of Personality and Social Psychology,* vol. 77, no. 6, pp 1121-1134, 1999

[7] D. Dunning, "Chapter five. The Dunning Kruger Effect: On being ignorant of one's own ignorance" *Advances in Experimental Social Psychology*, vol 44, pp. 247-296, 2011

[8] G. E. Gignac, and M. Zajenkowski "The Dunning-Kruger effect is (mostly) a statistical artefact: Valid approaches to testing the hypothesis with individual differences data" *Intelligence,* vol. 80, 2020, doi 10.1016/j.intell.2020.101449

[9] M. Mazor, and S. M. Fleming "The Dunning-Kruger effect revisited" *Nature Human Behaviour,* vol. 5, pp 677-678, 2021

[10] M. Parker "Why do Biden's votes not follow Benford's law?" YouTube video on channel Stand-up maths, https://youtu.be/etx0k1nLn78, 2020, accessed 2021-11-07

[11] M. Parker "Do these scatter plots reveal fraudulent vote-switching in Michigan?" YouTube video on channel Stand-up maths, https://youtu.be/aokNwKx7gM8, 2020, accessed 2021-11-07

[12] M. Parker "Why was Biden's win calculated to be ONE IN A QUADRILLION?" YouTube video on channel Stand-up maths, https://youtu.be/ua5aOFi-DKs, 2020, accessed 2021-11-07

[13] A. Burrows, J. Holman, S. Lancaster, T. Overton, A. Parsons, G: Pilling, and G Price, "Chemistry3 Introducing inorganic, organic, and physical chemistry. 4th edition" Oxford University Press, Oxford, United Kingdom, pp. 387-388, 2021

[14] D. Cowern, "Is energy always conserved?" YouTube video on channel Physics girl, https://youtu.be/GHCc9b2phn0, 2016, accessed 2021-11-07

[15] A. Flodström, Quoted by Ny Teknik under headline "Sagt Gjort", 2007 nr 47, page 2, Nov 21 2007

[16] A. T. Groover "What genes make a tree a tree?" *Trends in Plant Science,* vol. 10(5), pp. 210-214, 2005

[17] C. Silén, “Mellan kaos och kosmos - om eget ansvar och självständighet i lärande” Ph.D. dissertation, Linköping Studies in Education and Psychology No. 73, Dept. Behav. Sci., Linköping Univ., Linköping, 2000.