

# What Energy Ideas Matter for Future Learning?

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**Abstract:** In a rapidly changing world, the ability to transfer one's knowledge is critical. Using the conceptualization of transfer as preparation for future learning, we investigated how students from two approaches to teaching energy that conceptualize energy differently, perform in a transfer task. We present first results that suggest that emphasizing energy ideas that are relevant across disciplines prepares students better for future learning than emphasizing those valued by the disciplinary tradition of physics.

## Preparing students for the future

We live in a rapidly changing world shaped by emerging technologies, cultural shifts, and pressing challenges such as climate change. As Andreas Schleicher points out, this has profound implications for education: instead of teaching a set of skills that last a lifetime, schools have to prepare students with a set of skills that prepares them to adapt to those rapid changes (Schleicher, 2018). In this light, the ability to transfer one's knowledge to make sense of new phenomena and solve new problems is critical. The focus in recent science standards, e.g., the US NGSS, on emphasizing learning around relatively few but powerful core ideas to support knowledge-in-use, is in line with this trend. However, how we can best assess to what extent students are able transfer their knowledge to new phenomena and what aspects of core ideas should be emphasized in instruction to support transfer is little researched (Penuel, Turner, Jacobs, Horne, & Sumner, 2019). Here, we present first results from a study that started to address this issue by investigating to what extent students from two instructional units that conceptualize energy differently, are prepared to transfer their knowledge to a new context.

## Transfer as preparation for future learning

In our study, we draw on the double-transfer paradigm (Bransford & Schwartz, 1999) that conceptualizes transfer as preparation for future learning (PFL). The PFL perspective emphasizes that in the majority of situations where students have to transfer their knowledge, they will not be on their own. Instead, when they face a problem such as trying to figure out why the battery of their cell phone has died unexpectedly fast, students have access to a plethora of knowledge resources. Therefore, the double-transfer paradigm tries to mirror the everyday situations in which students will have to transfer their knowledge by including access to a learning resource. The learning resource however does not give away the answer to the problem. Thus, students will first have to use the knowledge that they bring to the assessment to make sense of the learning resource and then use the newly constructed knowledge and apply it to the actual transfer task.

## Energy and PFL

Energy cuts across the sciences and often provides a useful initial perspective on new phenomena as the principle of energy conservation generally applies. However, students often have a fragmented understanding of energy that is largely context dependent (Park & Liu, 2016). Nordine, Fortus, Lehari, Neumann, & Krajcik (2019) have theorized that a systems-transfer approach (STA) to teaching energy that does not introduce forms of energy but emphasizes the relationship between energy and systems may support a more cross-cutting understanding of energy. To investigate this, we asked How does a STA unit compared to a traditional forms-based unit prepare students for future learning?

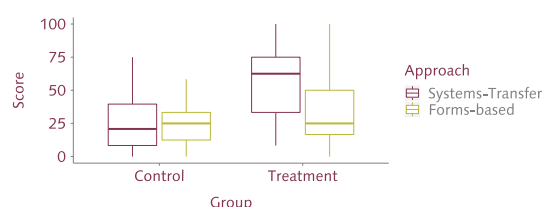
## Methods

The study took place in the midwestern US in 7<sup>th</sup> grade as part of a larger study where we investigated students learning in two ca. 10-week long energy units – a forms-based and a STA unit. The PFL task was administered to 54 students from one teacher teaching the STA unit and 51 students from another teacher teaching the forms-based unit after the end of the respective units. Students from each unit were randomly assigned to a control and treatment group for the PFL task. The PFL task is centered around the question of “How do instant heat packs work?” and structured as an inquiry activity. Initially, treatment and control group get a sheet that introduces the heat pack and get the opportunity to engage with the heat packs themselves and asked to provide their initial ideas

about how the heat pack works. Next, students in the treatment group get a text that explains how a heat pack works while students in the control group answer two heat pack science questions. When students in both groups are done with these activities, they get to watch a video about how the heat pack works. Finally, control group students get the learning resource and a chance to reflect on their learning. This ensures that the heat pack task as a whole provides a meaningful learning activity for all students regardless of whether they are in the treatment or control group. At the same time, students in the treatment group answer the heat pack science questions. The heat pack science questions are designed to target students' knowledge-in-use about energy. To answer our research question, we used qualitative content analysis to investigate what initial ideas students activated and ran a regression analysis on the science question scores with treatment and instructional approach as variables.

## Results

Our qualitative content analysis revealed that students generally activated similar ideas in the initial questions section. However, a small percentage of STA students activated ideas about energy transfer – key to making sense of the heat pack. The only energy related idea that some forms-based students activated was thermal energy, a rather descriptive idea. Figure 1 shows that the difference in scores on the heat pack science questions between control and treatment group is larger for STA students than for forms-based students.



**Figure 1.** Score on Heat Pack science questions for control and treatment group of both approaches.

A regression analysis (Table 1) confirms this with a statistically significant interaction effect between treatment and forms-based approach, indicating that forms-based students in the treatment group score considerably lower ( $d = 0.82$ ) than STA students in the treatment group.

**Table 1:** Regression table for the prediction of students score on the Heat Pack science questions

Variable	<i>B</i>	<i>SE B</i>	$\beta$	<i>p</i>	<i>R</i> <sup>2</sup>
Treatment (1 = in treatment group)	31.41	6.41	1.26	< .001	
Forms-based (1 = forms-based approach)	0.11	5.90	0.00	.99	.25
Forms-based x Treatment	-20.09	9.10	-0.81	.03	

## Discussion and outlook

Our results show that as theorized by Nordine et al. (2019), students in an STA unit appear better prepared for future learning than students in a forms-based approach. This has two important implication for the design of learning environments that prepare students for the future: 1) It matters *which* aspects of core ideas we emphasize in instruction, not just that we emphasize core ideas at all. 2) Supporting students in future learning may require emphasizing other aspects of core ideas than those valued by the respective disciplinary tradition. We are currently developing more PFL tasks for a follow up study that will cover more contexts and have a larger sample.

## References

- Bransford, J. D., & Schwartz, D. L. (1999). Rethinking Transfer: A Simple Proposal With Multiple Implications. *Review of Research in Education*, 24(1), 61–100.
- Nordine, J., Fortus, D., Lehavi, Y., Neumann, K., & Krajcik, J. (2019). Modelling energy transfers between systems to support energy knowledge in use. *Studies in Science Education*, 1–30.
- Park, M., & Liu, X. (2016). Assessing Understanding of the Energy Concept in Different Science Disciplines. *Science Education*.
- Penuel, W. R., Turner, M. L., Jacobs, J. K., Horne, K., & Sumner, T. (2019). Developing tasks to assess phenomenon-based science learning: Challenges and lessons learned from building proximal transfer tasks. *Science Education*.
- Schleicher, A. (2018). The case for 21st-century learning.