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Original citation & hyperlink:
van der Horst, D. , Harrison, C. , Staddon, S. and Wood, G. (2015) Improving energy literacy through student-led fieldwork – at home. Journal of Geography in Higher Education, volume 40 (1): 67-76
http://dx.doi.org/10.1016/j.future.2015.10.014

DOI 10.1016/j.future.2015.10.014
ISSN 0167-739X

Publisher: Taylor and Francis

Improving Energy Literacy through Student-Led Fieldwork - at Home.

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Abstract
'Energy literacy' is of great interest to those researching sustainable consumption, particularly with regards its relationship to domestic energy use. This paper reflects on the pedagogic aspects of fieldwork recently carried out by undergraduate geography students in their own homes to assess energy related technologies and practices, and how these come together into a singular, aggregated number produced by the energy meter. Drawing on Dewaters & Powers (2011) conceptualization of energy literacy as comprising cognitive, affective, and behavioral domains, we evaluate the experiences reported by the students and discuss next steps in expanding the exercise and learning.

Keywords
Energy literacy, energy citizens, domestic energy use, fieldwork, pedagogy, active learning

Introduction
The relationship between energy and geography is both intimate and complex. Cheap and abundant energy is the nemesis of geographical constraints, enabling us to conquer space, overcome climate and 'globalize' our lives, economy and society. However, given the role of fossil fuel consumption in anthropogenic climate change, our 21st century energy dilemma is how to flourish as a society without using quite so much (conventional) energy. This question of the legibility of the sustainability implications of our behavior comprises a challenge to researchers and educators alike. On the supply side, the visibility of extractive technologies to local communities has often been portrayed as a fundamental reason for local opposition (e.g. van der Horst, 2007). On the demand side the very opposite can be found: energy has been largely 'invisible' in the consumptive choices of our daily life (Burgess & Nye, 2008; Hargreaves et al., 2010).

Voluntary reductions in energy consumption are difficult to achieve without appropriate knowledge of energy consuming technologies and rates of energy use. Hence there is a need to improve 'energy literacy', equipping people to make more thoughtful, responsible energy-related decisions and actions. DeWaters and Powers (2011) conceptualize energy literacy as comprising three domains; cognitive (knowledge), affective (attitudes, values) and behavioral, with an energy literate individual as:

> "…one who has a sound conceptual knowledge base as well as a thorough understanding of how energy is used in everyday life, understands the impact that energy production and consumption have on all spheres of our environment and

> society, is sympathetic to the need for energy conservation and the need to develop alternatives to fossil fuel-based energy resources, is cognizant of the impact that personal energy-related decisions and actions have on the global community, and – most importantly – strives to make choices and exhibit behaviors that reflect these attitudes with respect to energy resource development and energy consumption" (DeWaters & Powers, 2011, p.1700).

Keen to bridge our (energy) research and (geography) teaching interests, this paper is our first step in sharing teaching ideas, experience and expertise as we are developing new energy courses in the UK and US. In support of the goal of this Symposium issue focusing on teaching energy geographies (Thoyre & Harrison, this issue), this paper reports and reflects on an exercise by undergraduate Geography students to assess their domestic energy use. Running for the first time in September 2014, this exercise aimed to build energy literacy through a combination of active learning, smart meter technologies and reflection. In the following section we expose the pedagogic foundations of this fieldwork exercise. We then summarize the exercise and report on the experiences of the students. We conclude by reflecting on the ways in which the exercise relates to the cognitive, affective and behavioural aspects of energy literacy.

Pedagogic Foundations

Energy literacy, as defined above, implies a stage beyond simply gaining knowledge: learners should have the capacity to assimilate and critique information they receive, applying this to their choices and actions, and ultimately exhibiting sustainable behavior as a result (St. Clair, 2003). For this to take place, constructivist learning (where a route from current knowledge to new information is paved through applications to real life (Hein, 1991)) and transformative learning (where learners are encouraged to reflect upon problematic perspectives and mindsets (Mezirow, 2009)) are paramount.

Constructivist learning advocates starting on the scale of the individual (and familiar situations), and moving from there. It is a kind of active learning that leads to students making their own choices rather than simply taking on the view of the educator (Cutter-Mackenzie & Smith, 2003). There are a number of active learning approaches with constructivist roots, including enquiry-based learning (EBL) and problem-based learning (PBL). EBL tends to be more shaped by the educator while PBL is framed by the student (Pawson et al., 2006). Both processes are scaffolded and guided by the course leader, such as by asking questions or providing explanations, and focus on real-life issues (Hmelo-Silver et al., 2007). EBL encourages direct student involvement in research, and it can be the case that staff and students work together in communities of enquiry (Healey, 2005).

Furthermore, experiential learning (learning from direct experience) can enable both cognitive (knowledge-based) and affective (behavior-based) learning. Using real-world settings makes the authenticity of learning activities clear and connects the lecture theatre to the home. By reflecting on everyday experience (through a cycle of concrete experience, observation and reflection, forming abstract concepts and testing in new situations), learning actively changes the way an environment is viewed and interacted with (Kolb, 1984).

In our exercise, students conduct fieldwork in their own homes in relation to their own energy use. Moving fieldwork into the home brings the concept closer to the definition of experiential learning, but reflection upon experience is an essential additional ingredient for learning to take place. The home, as a site for fieldwork, has been thoroughly interrogated by recent geographic research (Blunt and Dowling, 2006; Brickell 2012). At the heart of fieldwork is a direct, active encounter with 'the other' (Hope, 2009, p.180) and it is this encounter, it is argued, which makes fieldwork challenging, at times difficult and thus such a valuable mode of learning for geography. The student exercise therefore offers some peculiarities worth considering; firstly, it is not in 'the field' as commonly perceived, either as a distant physical land or with communities which challenge student's cultural and or emotional norms – instead it is in the student's own home; secondly, the fieldwork is not with (potentially distant) 'others', but rather with themselves; thirdly, the fieldwork (at times) is mediated through the use of technology, which may be thought of as an additional 'other' with which encounters are experienced; and fourthly and finally, the 'host community' for the fieldwork is not a distant one left behind when the fieldwork is complete, but in the form of flatmates, landlords, friends and family, is one that the students will continue to share a home with long after the exercise is complete. These issues demand scrutiny of the energy literacy exercise on pedagogical, as well as ethical, grounds.

The Student Exercise

The energy monitoring exercise is structured to provide students with a basic understanding of how electricity is used in their homes, the factors that are driving it, and how it varies (e.g. by season). The goal is to monitor overall electricity consumption, and to understand the extent to which lighting, space conditioning, water heating, and various appliances contribute to total consumption. To accomplish this, the exercise takes the following steps.

Students are provided with detailed exercise instructions (available at X - *deleted for anonymous peer review*), a spreadsheet template to guide and standardize their data collection (see Figure 1), and a watt meter to use over the course of the exercise. The exercise takes time - there is a lot of data to be collected - so students are required to collect data over the course of one week, with additional time given to analyse and write up their results.

		Day						
	Activity Performed	1	2	3	4	5	6	7
Stage 1	**Collect Power Ratings for Appliances**							
	Estimate Weekly Appliance Electricity Consumption							
Stage 2	**Measure Individual Appliances with Watt Meter**							
Stage 3	**Check Total Consumption At Meter**							

Figure 1. Stages of Data Collection

In the first step of the exercise (see Figure 1 which lays out each stage), students are asked to make an inventory of their dwelling's major appliances, the appliance's power rating, and their estimated time of use of that appliance per day. While what counts as a 'major' appliance is in part specified in the assignment, students are also instructed to include other electric appliances that they frequently use. This information is extrapolated to calculate electricity consumption per week, and then multiplied by the local per kilowatt-hour electricity cost. While no actual electricity use data is collected in this step, students must take some time to think about their daily practices and link them to energy consumption. For example, how long do they watch television each day, how much energy does this use, and how much does this cost them? This initial exercise also requires students to do independent research on their appliances, which may or may not have power ratings clearly marked. Students are also required to find what their electricity rate is, which requires them to view their electricity bill, or to search their local electric utility rate schedule. This exposes them to the variety of rates most utilities charge (i.e. residential, commercial, or industrial), as well as how rates may vary seasonally or by consumption level.

In some cases, students may be unable to find information for the exact power rating of their appliance. In these cases, we ask that they find a similar product, or use generic information. In their reporting, we require them to identify when they have done this, and to cite the alternate appliance or data source.

In the second step, the watt meters are deployed to collect data on each appliance's actual electricity consumption. For appliances that have variable consumption, such as televisions with an on and standby mode, students are required to leave items plugged into the meter for several days. For appliances without a standby mode, such as toasters and hair dryers, students can plug the appliance in for only the time that it is in use. This data is again extrapolated out for the week and the cost of operating each appliance per week is calculated. Students then compare this data to their estimates, are asked to note the differences in estimated versus actual consumption, and consider some of the reasons for this discrepancy.

In the third and final step, students are asked to track their daily total household electricity consumption at the meter over the course of seven days. As the following section shows, the total electricity consumption collected in stage three is particularly eye-opening for students. Once the consumption data collected on individual appliances is tallied, students are asked to reflect on the difference between the consumption at the meter and the data they were able to collect at the appliance level. The student voices that follow were collected as part of the exercise[1]. As part of the assignment, students were asked to reflect in writing on what they learned in the process of measuring their home electricity use. They were prompted to think both about the material outcomes of the exercise (e.g. which appliances consumed more electricity than they would have guess) as well as more 'social' challenges that shaped their energy consumption (e.g. social norms, behaviour of flatmates, etc.).

Key findings reported by the students

A pilot of this approach was run in September 2014 with 12 upper level undergraduate students at a large public university located in the southern United States[2]. While the total number of data points collected by the students is relatively small, student experiences and feedback clearly show the potential for active learning as well as several pedagogical opportunities. Four particular findings are illustrative of this.

First, in reference to Stage Two of the assignment, students were frequently surprised by the amount of electricity appliances were using, as well as unexpected sources of electricity use. As one student noted, "the microwave uses a surprisingly large amount of power in the short

[1] Students were notified that their responses would be used anonymously as part of this study.

[2] In order to simplify the exercise, we did not engage the students with the temporal and spatial variability of the carbon intensity of the grid.

time it is used." Students described their television and video game console as "constantly sucking power [even] when off," and their coffee maker using "a ridiculous amount of energy." For others, it was the comparison between appliances that was most surprising. One student, referring to chargers and blenders, noted that "little appliances use more electricity than people think," while another found that their microwave used more electricity than their clothes washer.

Second, the role of social practices in reducing energy demand, as well as the limits to practices as a consumption reducer, were highlighted by many students. One student noted that their household keeps the apartment too cold, as they deducted from the difference between their total consumption in Stage 3 and their monitored consumption in Stage 2 that they were using too much electricity for air conditioning, an appliance that typically cannot be measured. Another student reported that less energy was used in their apartment on weekends because people were home and more actively managing appliances and thermostats. However, numerous students detected the relatively limited impact that lighting had on their overall consumption. As one student said, "I thought that turning off my lights more often would save a lot of energy, but it really doesn't."

Following from this is a third finding for students: while there are some energy consuming activities that can be actively monitored and managed, there are others that are more difficult to assess and change. One challenge many students confronted was an inability to meter numerous appliances – especially dishwashers and clothes dryers that are hard-wired into houses or have receptacles that are incompatible with watt-meters. While this limited the ability of students to accurately break down their overall usage, it did provide an opportunity to discuss differing wiring capacities, the differing power needs of some appliances, and how the design of the home (especially the codes that dictate its wiring) and appliances can essentially lock in particular patterns of electricity consumption. This is especially the case for students, who tend to be renting or living in university housing that allows very little change in the primary energy consuming systems and infrastructure.

Finally, the process of comparing overall electricity consumption to monitored consumption provided a surprise for many students, as a significant amount of electricity consumption was still unaccounted for. This highlights the two most significant components of household energy consumption: space heating and cooling and hot water heating. Given the hot climate in which the pilot study took place[3], the role of air conditioning in energy consumption was particularly important. For students, the inability to directly monitor the consumption of these high energy users, as well as their inability to alter their dwelling, makes clear several challenges to altering societal energy consumption behaviour more broadly. Pedagogically, this challenge provides an opportunity to point to the fixity and longevity of some appliances, particularly those using the most electricity. It also highlights the so-called split incentive problem - as a renter, it is nearly impossible to change these appliances, or the built environment in which they operate (e.g. adding insulation or sealing drafts), yet landlords, because they are not paying energy bills, have no incentive to improve energy efficiency.

University students can occasionally face challenges that make monitoring energy consumption difficult. Some students live in university housing or apartment complexes

[3] During the period of the pilot study, the mean high temperature was 85˚F (29.4˚ C) with 362 cooling degree days.

where electricity costs are already factored into rents. Many of those units do not have individual electricity meters or have shared hot water heating, which makes collecting and accessing overall consumption and appliance data difficult. Some students may be facing personal challenges that make monitoring electricity data impossible, such as disconnections from service due to bill non-payment. The key in each of these circumstances is flexibility, encouraging students to find creative solutions on their own, and using these challenges as teaching moments. As an example, for students unable to monitor their overall consumption, in subsequent assignments we will ask them to consider how that might affect their energy consumption behaviour.

The student exercise has been very revealing in understanding the benefits, practicalities and limits of calculating and monitoring domestic energy use. In order to identify how the exercise may be expanded and improved upon for future teaching, we now consider its relationship to ideas of energy literacy.

Discussion – Student fieldwork and energy literacy

Drawing on the definition of an energy literate person given in the introduction to this paper (DeWaters & Powers, 2011), we structure our discussion according to the cognitive, affective and behavioral elements of energy literacy, reflecting on the extent to which the current exercise has enabled these types of learning, and identifying the next steps to extend and improve the exercise. Finally, instead of 'concluding' what is an ongoing learning process, we 'zoom out' to point at the potential of energy literacy education to strengthen notions of citizenship and to bridge the gap between teaching and research.

Promoting cognitive elements of energy literacy

It is clear that the above exercise promotes certain cognitive elements of energy literacy amongst students, including knowledge about the power ratings of appliances, the appliances' actual wattage, and total electricity consumption for the household. By combining ratings and wattage with estimated times that appliances are used for, students gained an idea of their use of energy over time; however this is limited by the ability to estimate accurately the time an appliance is used over a longer period, and to account for natural rhythms and changes in this over the weekend, or due to changes in routines by participating students and/or their flat mates.

The students went on to gain knowledge of their total actual energy use for a week, which allowed them to consider the portion of that which is made up of space heating and cooling – a large portion. The inability to monitor all appliances was noted as a constraint to the current exercise; however this is one that potentially could be reduced through the use of more sophisticated smart metering technology which could apportion electricity use to particular appliances.

Whilst the students gained important technical knowledge about appliance energy consumption and their overall use of electricity i.e. "how energy is used in everyday life" this knowledge had little – directly – to do with "the impact…[of this] on all spheres of our environment and society…[nor] the impact that personal energy-related decisions and actions have on the global community" (DeWaters & Powers, 2011, p.1700). In order to address this element of energy literacy, additional classroom-based teaching may be required, through which they may gain for example a technical knowledge of energy units and ratings, an awareness of typical domestic energy usage around the world in order to place their own usage in context, the variable carbon intensity of 'the' grid and an appreciation of the environmental social and economic costs associated with energy production.

In order to understand to what extent such an exercise enables or promotes an increase or growth in students' level of energy literacy, it would also make sense to use some form of baseline survey before the exercise begins. This could be designed to capture their level of knowledge, firstly around the use of energy in everyday life and secondly around the impacts of that use on the environment and society. It would thus be important to know what formal teaching the student has received in energy related issues. A follow-up survey could be used post-exercise to see where gains in knowledge have been made by individual students.

Promoting affective elements of energy literacy

It is clear that the student-led exercise described above promotes certain affective elements of energy literacy, when for example the students talk about their surprise at the power rating and energy use of different appliances. This surprise could lead to changes in their attitudes and potentially values around energy. It should be noted that no attempt was made to measure changes in attitudes or values in the exercise described above. A pre- and post-exercise survey could be used to assess these.

Students also alluded to a number of social factors which impacted on the reduction of energy use in their homes. One student for example talks about their flatmates wanting to keep the apartment too cold, which points to the fact that their own sympathies towards energy reduction may in fact have to be balanced against the sympathies (or lack thereof) of those with whom they share a home. Pedagogically, fieldwork depends on a 'host community' and in this exercise that community comprises the flatmates or family of the student. There are also therefore ethical concerns over negotiations that aim to alter the energy use practices of others in the house.

Even if a pre- and post-exercise survey assessed changes in the affective domain of energy literacy i.e. attitudes and values, these may not translate neatly into changes in behavior, given the 'value-action gap' which highlights that attitudes do not necessarily match behavior (Kollmuss & Agyeman, 2002). Specific attention is therefore needed to consider the behavioural elements of energy literacy.

Promoting behavioral elements of energy literacy

The behavioral domain of energy literacy i.e. the putting into action of cognitive and affective elements, is at best implicit in the current exercise. It could be developed into an explicit objective by adding to the current exercise a second phase of scenario development, assessing and setting targets for behavior change tailored to individual students and households. As with cognitive and affective elements, the assessment of behavior requires pre- and post-exercise surveys, but a wider range of methods are available here, with on the one side the possibilities offered by digital monitoring equipment, (big) data analysis, the modeling of patterns of energy use over time or across households and (quantitative) surveys feeding into quantified scenarios of reduced consumption, and on the other side more qualitative assessment methods (self-assessment, group assessment), including journal keeping, the use of photos or videos, or discussions with flat mates to identify, understand and agree on changes in behaviors and practices.

It is however important to note that the current exercise has revealed several limitations for behavioral change of the students, including lack of control over appliance choice or building fabric; difficulty in monitoring some appliances; and energy costs sometimes being factored into rent payments. This demonstrates the problem in considering behavior change as following learning about energy use within an educational process (cf. Wood et al., 2014). Students should certainly not be considered energy *illiterate* simply because they are unable to change circumstances outside their control.

Pedagogic foundations revisited

Attention to behavior and behavior change also links to the learning processes involved in the exercise. While students in the exercise explored their own personal energy consumption and engaged in experiential learning by building a sense of understanding through the experience, reflection and the opportunity to test new ways of doing things would be needed in order to complete Kolb's experiential learning cycle. This may well have been undertaken informally by interested students but there is scope to include this in future exercises. Reflective learning could be integrated into the exercise with a journal-keeping activity, while there is potential to explore impact on behaviors with follow-up surveys or interviews with students. Encouraging students to investigate their own lines of enquiry would also develop the exercise further as EBL (Kahn & O'Rourke, 2005). Equally, there is scope for practice-oriented, participatory (POP) methods such as workshops to consider possible alternative futures and deliberate scenarios (cf. Davies and Doyle, 2015). Group exercises such as this move the participant away from individual behavior to consider wider sociocultural norms and practices, and the shifts that might occur (or be needed) in response to natural resource pressures and emerging technologies.

The home is clearly a productive site in which to conduct fieldwork and one which provides the challenges central to fieldwork (Hope 2009), despite its familiarity (although the technology used to monitor energy use is unfamiliar and was clearly important in creating opportunities for new learning). Constructivist learning is thought to be facilitated by the familiar however this exercise has helped to reveal the wider challenges associated with energy literacy and reducing domestic energy demand; that it extends beyond the individual and the home, depending instead on the socio-material organization of energy use (Shove et al., 2014).

Energy literacy or energy citizens?

This exercise could be seen as an important early step for students to progress from energy 'consumers' towards energy 'citizens', aware of international and intergenerational responsibilities and the knock-on effects of their behaviors (Dobson, 2007). There is scope therefore to ensure the fieldwork exercise sits within discussions of the evolving but fundamental role of energy in society, touching on a wide variety of concerns, from security and health, to freedom, accountability and responsibility. This would also address DeWaters and Powers' (2011, p.1700) reference to an energy literate individual understanding impacts on "the global community", and could allow for expressions of energy literacy and citizenship in different ways; for example a student choosing to campaign for more sustainable resource use, rather than simply feeling frustrated at the lack of behavioral changes they personally are able to make.

Moving forward, we can see an agenda for developing teaching for energy literacy within higher education. Firstly, further integration of fieldwork enquiry-based exercises into energy teaching would be beneficial. This could be through exploring students' socio-material relations with energy-using or saving objects (as well as smart metering technologies) and through a range of qualitative and quantitative means in order to capture aspects of energy know-how alongside numerical data, whilst also reflecting different student learning styles. Formal integration of opportunities for reflection in these exercises would increase the likelihood of experiential learning exercises having both cognitive and affective impacts, as well as the additional benefit of gaining rich qualitative data, as enquiry-based learning encourages student involvement in staff research (Healey, 2005). For our own teaching and research portfolio, and for out-reach work by ourselves and/with our students, we see this integration as an essential step to help citizens understand and interrogate the links between the ongoing smart energy revolution (smart metering alone is a 'black box' that carries hidden issues of control, accountability, privacy) and the energy dimensions of domestic practices and everyday lives in a society struggling to find more sustainable ways forward.

Acknowledgements

This work was supported by the EPSRC (Engineering and Physical Sciences Research Council, UK) projects TEDDINET www.teddinet.org [grant number EP/L013681/1] and Smarter Households [grant number EP/K002716/1]. We are indebted to the students who trialed the exercise and shared their experiences with us. We thank John Farquhar, Erika Warnatzsch and three anonymous referees for their useful feedback.

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