Air-source heat pumps in the secondary physics laboratory

Daniel COTTLE (1), Robert CAMPBELL (2)

(1) University of Birmingham, School of Physics and Astronomy and School of Education, Edgbaston, Birmingham, UK
(2) University of Birmingham School, Selly Oak, Birmingham, UK

Abstract. Decarbonisation of home heating in England is accelerating through the phasing out of gas boilers and the introduction of air-source heat pumps. We argue that the physics secondary school curriculum in England therefore needs to change to include understanding of the thermodynamic principles of operation of air-source heat pumps. We present details of a classroom activity to demonstrate the efficiency of air-source heat pumps compared to other forms of home heating.

Introduction

There is growing anxiety among young people about how climate change will affect their future lives, coupled with frustration that politicians and adults in general do not seem to be taking these worries as seriously as they do [1]. Increasing numbers of young people are being motivated to climate activism and do not feel that the school science curriculum in England satisfies their desire to understand the issues [2]. One key part of the national strategy to reduce carbon emissions in the UK is the phasing out of fossil fuel consuming gas boilers for home heating and replacing these with electrically operated air-source heat pumps [3]. In 2019 17% of the total carbon dioxide emissions in the UK came from home heating which is equivalent to the combined contribution of all petrol and diesel cars [4]. Despite this national effort, many young people remain unable to evaluate the potential benefits of air-source heat pumps as neither descriptions of the technology nor the underlying thermodynamic principles of operation are part of the normal school physics curriculum. This curriculum in England was last revised in 2015 [5] and has as one of its aims, the need to ensure pupils 'are equipped with the scientific knowledge required to understand the uses and implications of science, today and for the future.' We suggest that due to the rapid pace of innovation in climate technology, it is currently failing in this aim and risks leaving children ill-equipped to make personal life choices relating to their homes or contribute in an informed way to democratic discourse on measures to mitigate the effects of climate change. We go on to describe an investigative learning activity [6], co-developed between university departments of physics and education and a secondary school in England, which could be easily integrated into current secondary school physics curricula to address some of these concerns.

Heat Pump for Classroom Teaching

An air-source heat pump for home heating is a device that uses a thermodynamic refrigeration cycle to transfer stored thermal energy in the moving molecules of air outside a house to an interior thermal store in hot water. Commercial heat pumps are often large, and the refrigerants used are also toxic, flammable and harmful to the atmosphere. These factors make classroom use difficult. There are heat pumps produced for learning, but these are often aimed at either undergraduate chemical engineering students or trainee heating engineers and so are also large and expensive. To solve these problems we adapted a compact, safe, sealed unit normally used to heat water in home swimming pools. Figure 1 shows how our air source heat pump was set up in the school laboratory.

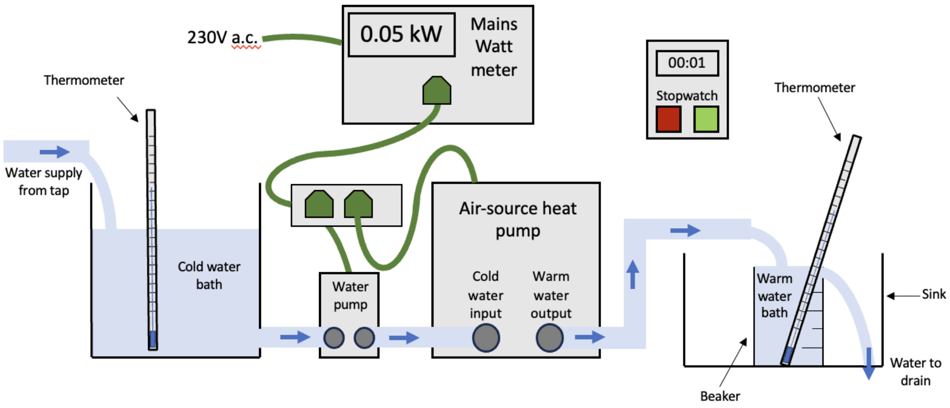

Fig. 1. Laboratory set-up of air-source heat pump and other equipment

Pedagogical Innovation

Data were collected that demonstrated the learning potential of the activity and some suggested investigations were devised. These included: Investigating the difference between measurements of efficiency and coefficient of performance, investigating the effect of ambient air temperature of the efficiency of operation of an air source heat pump. These investigations were selected to engage pupil interest around comparing air source heat pumps to other kinds of home heating and to provoke scientific discussion of wider questions such as: Will air source heat pumps be effective even when it is cold outside? How can the claims of manufacturers of heat pumps e.g. '300% efficient' be evaluated? The investigations were tested and refined by teachers and a group of 16-18 year old pupils at a secondary school in Birmingham. Reflections and comments were collected from teachers who used the investigations. They revealed how some basic scientific principles such as; efficiency, change of state, specific heat capacity and latent heat, could be applied to the heat pump investigation to support pupil understanding without requiring more advanced thermodynamics. They also reported high motivation and engagement of pupils.

References

[1] C. Hickman, E. Marks, P. Pihkala, S. Clayton, R. E. Lewandowski, E. Mayall, B. Wray, C. Mellor, L. van Susteren, Climate anxiety in children and young people and their beliefs about government responses to climate change: a global survey. *Lancet Planet. Health* **5** (2022) 863-873

[2] BBC News 2022 (available at: https://www.bbc.co.uk/news/science-environment-62245185) (Accessed 1 February 2024)

[3] HM Government, Net zero strategy: build back greener (available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1033990/net-zero-strategy-beis.pdf) (Accessed 1 February 2024)

[4] UK Parliament Business, Energy and industrial strategy committee Decarbonising heat in homes. Seventh Report of Session 2021–22 (available at: https://committees.parliament.uk/publications/8742/documents/88647/default/) (Accessed 1 February 2024)

[5] Department for Education, National curriculum in England: science programmes of study 2015 (available at: https://www.gov.uk/government/publications/nationalcurriculum-in-england-science-programmesof-study/national-curriculum-in-englandscience-programmes-of-study) (Accessed 1 February 2024)

[6] Cottle, D. and Campbell, R. 2024 Investigating the Efficiency of Air-Source Heat Pumps in the Secondary School Physics Laboratory. *Phys. Educ* 59 015023