Innovations in Science Education and Technology

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Thermal Cameras in Science Education

Springer

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Foreword

There is a long history of using sensors to promote inquiry in science education, pioneered notably by Dr. Robert F. Tinker more than three decades ago. In most cases, a few sensors are used to measure certain physical or chemical properties. These sensors are then connected to a computer that logs their measurements. Students typically use a line graph to plot the incoming data as a function of time to visualize the scientific effect under investigation. Through observing how a property changes graphically in response to a stimulus in the real world, students develop a concrete idea about the causal relationship between the variables in question.

Since students can arbitrarily position a sensor in an experiment, educators often need to explicitly prescribe where and when students should put it in order to capture the data as intended. While this type of cookbook-like instruction ensures that students do not miss the chance to observe the due phenomenon, it may deprive them of the opportunities to make their own scientific discoveries and the excitement experienced in such intellectual processes.

Thermal imaging provides a novel technology to support authentic science inquiry without taking away the joy of discovery. A thermal camera automatically gathers a large array of radiometric data for immediately rendering an intuitive, salient heat map visualization of a phenomenon. Such a real-time, full-field visualization of an experiment enables students to discover important details of the emergent phenomena that would otherwise go unnoticed (e.g., the thermal energy released as a result of water molecules making hydrogen bonds with cellulose molecules when a water drop falls onto a piece of dry paper). Data collection is also made as convenient as taking a picture or recording a video just like using a conventional digital camera, freeing students from tedious procedures of scanning an area with a pointwise sensor and focusing them on the fun part of doing science. Such transformative potential would not have been possible without the power of many: Compared with a single thermometer that outputs only a data point at a time, a thermal camera bundles thousands of microbolometers in a small optoelectronic device to produce a large quantity of data at once.

As this book demonstrates, science educators have been tapping into the learning and teaching potential of thermal imaging not long after it was invented. With the plummet of price and the integration with smartphones in recent years, thermal cameras have never been more accessible to students and teachers. However, for the technology to take root and its application to grow in science education, we will need further research and development to convince schools to seriously invest in it. To this end, there may be three directions that are worth considering.

First, it is important to keep informing teachers that thermal imaging can be used to visualize any physical, chemical, and biological processes that absorb or release heat. In other words, *anything that leaves a trace of heat leaves a trace of itself under a thermal camera*. Based on this principle, we can use thermal energy as a universal indicator (passive or active) to investigate many questions in science. For example, what affects the rate of a chemical reaction can be studied using thermal imaging as a qualitative method. In the case of an endothermic reaction such as baking soda with vinegar, a petri dish filled with an aqueous reactant that is initially warm will exhibit a larger drop in temperature than another one that is initially cool when the reaction completes, suggesting that increasing temperature can speed up the reaction. Often, the challenge in broadening the application scope of thermal imaging is that it requires the participation of domain scientists to design, test, and optimize the thermal imaging equivalents of existing experimental techniques in their curricula and determine whether there are sufficient advantages to justify the conversion. This is by no means a trivial task. But if most teachers only view a thermal camera as a tool for seeing heat and are unaware of its broader applications, it would remain unlikely that schools adopt it as a main instrument for their science labs—especially in underserved districts that have a cash-strapped science budget.

Second, it is important to develop different types of apps based on the smartphone versions of thermal cameras to meet diverse needs in formal and informal science education. As a *mobile lab-on-a-chip* that can be used anywhere and connected to the cloud as part of the emerging Internet of Things, a thermal camera has tremendous potential for learning and teaching in different settings, particularly when integrated with other technologies. For example, the Infrared Street View project funded by the U.S. National Science Foundation at the Institute for Future Intelligence is a citizen science program that engages students to create thermal panoramas of their communities to survey their thermal landscapes. The project uses smartphone sensors to determine the location and orientation of a thermal image being captured by a thermal camera attached to the smartphone. Such thermal landscapes provide rich information about building energy efficiency, urban heat islands, solar energy potential, wildfire prevention, and so on that are relevant to personal issues in everyday life and global issues about climate change.

Third, it is important to develop learning and teaching theories to uncover the instructional power of thermal imaging as an example of *augmented cognition*, on a par with the active educational research on augmented reality. Many science concepts are difficult to students because they cannot be readily seen in the real world. One can only imagine how much thermal vision could help students overcome those cognitive barriers by simply empowering them with an additional sense to see a whole new world that is previously hidden from them. On the other hand, we all know that no technology can miraculously become a good educational tool without research to unpack how people may learn and teach with it. Sound theoretical framing and solid empirical evidence based on appropriate principles and approaches from the learning sciences would help us make a more compelling case for thermal imaging to science educators and policy makers.

Without a doubt, the efforts of the small international community represented by the contributors to this book are highly commendable. With their foundational work and continuous commitment, the power of thermal imaging is bound to enlighten more students around the world in the future. It is also our hope that this book will inspire even more applications to push the envelope of this fascinating field.

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