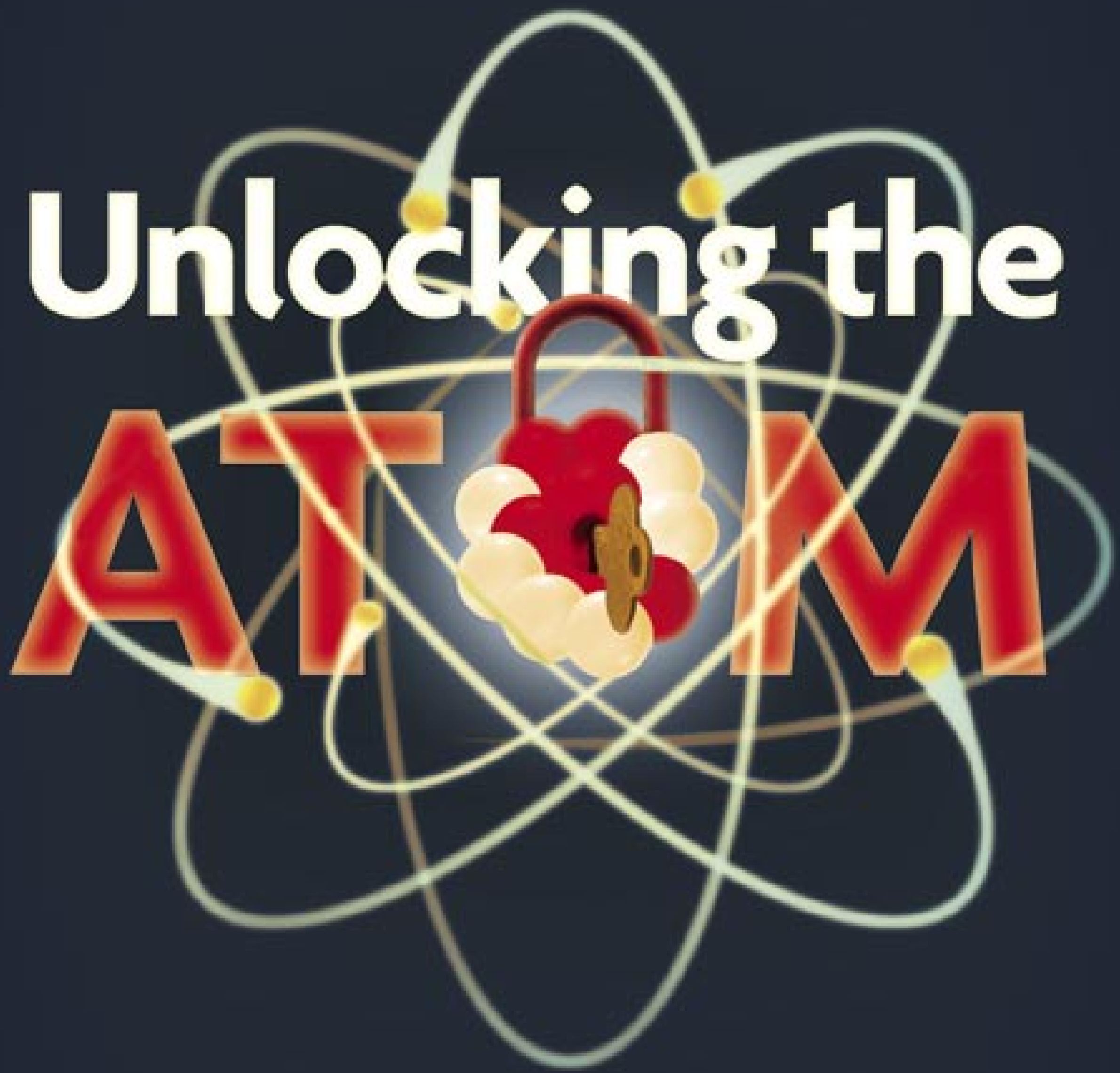

Students assume the roles of eight scientists to explore the atomic model

Jennifer L. Craft and Jacqueline S. Miller

In this project, high school chemistry students investigate atomic structure from a historical perspective. Assuming the personas of eight legendary scientists and their assistants, students stage a mock gathering to explore the evolution of the atomic model. This role-playing activity may also serve as a template for weaving the rich history of science into other subject areas.

Project and rationale

Many students fail to realize that science is not an absolute truth but a human endeavor, full of interesting discoveries, stories, and missteps. Scientific knowledge is ever evolving, questions of yesterday inform the experiments of today, and seemingly small advances (even blunders!) can be instrumental in shaping our views of the natural world. The *National Science Education Standards* (NRC 1996) recognize the efficacy of teaching science within the context of history, emphasizing the evolution of concepts, models, and theories. By studying science in a historical context, students view themselves less as spectators and more as participants in this human quest for truth and understanding.

The development of the modern atomic model marks one of the greatest accomplishments and most interesting scientific stories of the last 200 years. Designed as a part of *Foundation Science* (EDC 2005)—a three-year high school science curriculum now in development at Education Development Center, Inc.—the project outlined here asks high school chemistry students to explore atomic structure from a historical perspective. Assuming the personas of eight legendary scientists and their assistants, students stage a gathering to probe the evolution of the atomic model.

Students research the experimental evidence for the construction of this model as well as the lives and thought processes of the scientists involved. Each scientist group presents their research to the rest of the class, delving further into the details and complexities of atomic theory. Presentations are given in their historical, chronological order, underscoring the incremental nature of scientific advancement. The project culminates in individually written news stories about the "meeting of the minds," an assignment that allows students to weave science history, modern atomic theory, and their own twist on events that might transpire if deceased scientists could converse.

Project management and timeline

Two weeks prior to the presentation date, I introduced the project, timeline, and expectations (Figure 1, p. 26) to my four chemistry classes (mix of grades 10 and 11). Following submission of their top three scientist choices, I divided students into teams of two or three and assigned the roles of scientists such as John Dalton, Marie Curie, Erwin Schrödinger, and their assistants (Figure 2, p. 27). They had been summoned, students were told, to attend a historic gathering organized by the pre-Socratic Greek philosopher Thales. Thales, believed by many to be the founder of natural philosophy, was the first person to suggest that all matter was unified by a common building block, although he incorrectly identified that building block as water.

To prepare for the gathering, students had to research the personal stories and discoveries that led to the development of the modern atomic model. During the first week, teams were given one 50-minute planning period to begin researching their scientist and to develop a strategy for completing the project. During the second week, teams were given an additional 50-minute planning period to finalize project details, practice presentations, and ask questions. All other research and preparation were completed outside the classroom (in lieu of regular homework assignments for the two-week period). During the third week, each group met with me outside of class to go over questions related to difficult theoretical or experimental concepts and presentation content.

My classes delivered their presentations in one 80-minute class period (our designated laboratory day). If this time option does not exist, I recommend devoting two 50-minute class periods to these presentations, allowing time for both the presentations and 2–3 minutes for questions, as my students were markedly curious about the historical characters and their discoveries. Students were given one week from the day of the presentations to assemble and submit a news story on Thales's gathering (Figure 1). While the precise format of this independent, written assignment was left to students, a guideline of 500–1,000 words was set for news reports and feature articles.

Presentations

Playing the part of the Greek philosopher Thales (complete with a toga and gray wig), I began the meeting by introducing the life and work of Thales, including his hypotheses on matter: "The world appears to be filled with things that are all very different from each other. However, I believe there is an underlying structure that connects all matter. Perhaps all substances are just combinations of a few simpler substances." I went on to outline Thales's incorrect identification of water as the common, basic building block of matter and fundamental questions to be addressed at the gathering (e.g., What is the nature of matter? Is there an underlying structure that connects all matter?). One student recorded these questions on the board to reinforce key ideas and allow time for the class to reflect on the day's agenda and objectives.

Thales's welcoming remarks were followed by presentations given by the eight scientists and their assistants. Many groups began by having the assistants outline the background and scientific achievements of their mentor scientist. The scientists then presented their experiments and discoveries related to the atom and its internal structure. Groups were encouraged to supplement their presentations with visuals (PowerPoint presentations, posters, or three-dimensional models) and interactive activities (Figure 2). Student question/answer sessions were often accompanied by brief teacher summaries to underline important concepts and events, clarify connections, and prompt students to reflect on the progression of scientific theories and models. We ended our meeting with a round of applause for all attendees and words of gratitude from a newly enlightened Thales.

News stories

At the conclusion of Thales's gathering, I asked students to individually assemble a short outline of major events in atomic history, written in the form of a newspaper article or other newspaper feature. Students based the articles on their meeting notes, the abstracts, and postmeeting interviews with individual scientists (obtained outside of class). While the presentations allowed students to focus on individual lives and achievements, the news-story assignment forced them to reflect on and synthesize big-picture ideas: The intersecting stories of eight individuals, the progression of scientific thought, and our modern understanding of atomic structure.

FIGURE 1

Student project outline.

Background

You are a scientist or scientist's assistant, and you have been summoned to attend a historical gathering organized by Greek philosopher and scientist Thales. As a scientist of the 19th or 20th century, you will need to imagine traveling far back in time to 540 BC. The central question to be addressed involves the nature of matter: Is there an underlying structure that connects all matter? Thales has chosen you, the experts of the "modern" world, to attend his gathering and share your stories.

Project overview

Your team will prepare a five-to-eight minute presentation on your scientist's life, scientific achievements, and contributions to our understanding of matter or atomic structure. Assuming the roles of scientist and assistants, your team will share personal stories and your piece of atomic history at Thales' gathering. At the conclusion of the gathering, you will compile and submit a news story on the event (one story per student).

Part I: The presentation

- Begin by researching your scientist's life, scientific achievements, and contributions to our understanding of matter or atomic structure. When and where was your scientist born? Where was your scientist educated? What experiments led to your scientist's discoveries? Does your scientist's model of the atom fit with experimental data? How did the findings of your scientist advance our understanding of atomic structure?
- Explore a variety of sources to obtain information (e.g., textbooks, library books, periodicals, the internet). Be certain to properly document your sources.
- Assemble and submit a one-page abstract highlighting important ideas and facts covered in your presentation. Document all sources in a properly formatted bibliography. This abstract will be distributed to all members of the class on the day of the presentations.
- Use of visuals (PowerPoint, posters, or three-dimensional models) and interactive activities is encouraged.
- Try to put yourself in the shoes of your scientist or assistants. Although not required, costumes may be used to enhance your presentation.

Part II: The news story

- On the day of the gathering, take detailed notes on the event. What was the order of events? What did each scientist contribute to our modern atomic model? How did the various participants interact?
- Decide on the format of your news story. While accuracy of historical and scientific information is essential, the format of your story remains flexible. For example, you may choose to convey the story in a standard news report, a feature article, an editorial, a gossip column, or a comic strip.
- Use information provided in the abstracts to supplement your notes; should you need additional information, feel free to interview other scientists or their assistants after the gathering.

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FIGURE 2

The scientists (teacher handout).

Scientist	Key achievements	Contributions to understanding the atom	Examples of visuals and interactive activities
Thales	Founder of school of natural philosophy; introduced mathematics and astronomy to the Greeks	All matter is united by a common underlying structure; water is the common building block from which all matter is made (an incorrect hypothesis)	Host of the scientific gathering
John Dalton	Interested in meteorology and atmospheric chemistry; known as father of modern atomic theory; developed four postulates describing relationship between elements and compounds	Elements are made of atoms; atoms of given elements have unique characteristics; atoms combine in small, whole-number ratios to form compounds; different compounds contain atoms in different ratios	Ball-and-stick models of compounds with varied atomic ratios
Dimitri Mendeleev	Observed patterns among elements; credited with developing modern periodic table; predicted properties of new elements	Elements can be organized by their physical and chemical properties	Display of periodic tables through time; Periodic Table Activity*
Marie Curie	Discovered radium and polonium; used x-rays to examine injuries in WWII; won two Nobel Prizes (for physics in 1903 and chemistry in 1911)	Radiation is linked to the internal structure of the atom, not to the arrangement of atoms in a molecule	Photos of radium and polonium; photos of radiation-damaged tissue
J.J. Thomson	Discovered electron; contributed to development of mass spectrometer; received Nobel Prize for physics (1906)	Small, negatively charged electrons are contained within atoms	Cathode ray tube demonstration; diagram of cathode ray tube
Ernest Rutherford	Coined terms for alpha, beta, and gamma rays; discovered nucleus; used radioactive decay products to probe the atom; won Nobel Prize for chemistry (1908)	Tiny nucleus contains majority of atom's mass; the nucleus contains positive charge; electrons revolve around nucleus	Diagram of gold foil experiment
Niels Bohr	Theorized that electrons occupy shells or energy levels; explained that elemental properties are related to occupancy of outermost electron shells; showed that electrons can jump to higher shells with light absorption and fall back to lower shells with light emission; won Nobel Prize for physics (1922)	Electrons orbit the nucleus in discrete paths	Illustration of Bohr's atomic model; line spectra of various elements
Werner Heisenberg	Developed Uncertainty principle; spoke against use of atomic bomb in WWII; won Nobel Prize for physics (1932)	Electron locations are best described by areas of probability	Maps of probability density
Erwin Schrödinger	Merged Uncertainty principle and concept of wave-particle duality; devised famous wave equation to describe atomic orbitals; won Nobel Prize for physics (1933)	Electrons are housed in atomic orbitals of various shapes and energies	Models of *s*, *p*, and *d* atomic orbitals

*See chemistry module of *Foundation Science* (EDC 2005).

FIGURE 3

Sample scoring rubric for group presentations.

Criteria	1	2	3	4	Points
Content	Students did not address project goals and demonstrated little familiarity with factual/technical information.	Students addressed some project goals and demonstrated familiarity with factual/technical information.	Students addressed the majority of project goals and demonstrated good command of factual/technical information.	Students addressed all project goals and demonstrated superior command of factual/technical information.	
Organization	Presentation was unorganized and incomprehensible to audience.	Presentation was somewhat organized but sometimes difficult for audience to follow.	Presentation followed reasonably logical sequence and demonstrated few gaps in flow.	Presentation flowed easily and logically.	
Delivery	Delivery was unclear and inaudible to most. Students read from notes and failed to show interest in their work.	Delivery was reasonably clear and audible to most. Students used minimal eye contact and displayed minimal enthusiasm or interest in their work.	Delivery was reasonably clear and audible. Enthusiasm and eye contact were good, but delivery could have been more polished.	Delivery was clear, polished, and audible. Students kept audience engaged throughout with enthusiasm and eye contact.	
Research and resources	Students consulted few resources and failed to conduct adequate research. No sources were referenced in the desired format.	Students consulted few resources and failed to conduct thorough, detailed research. Students failed to distill information relevant to assignment. References were incomplete and/or did not use the desired format.	Students consulted several resources and conducted detailed research. Students made good attempts to distill relevant information. Sources were generally referenced in the desired format.	Students consulted many resources and conducted thorough, detailed research. Students effectively distilled relevant information. All sources were accurately referenced in the desired format.	
Visual aids	Students did not use visual aids.	Students used few visual aids. Relationships between visuals and content were not apparent.	Students used many visual aids, but connections between visuals and content were not optimal.	Students made effective use of visual aids to complement content and enhance interest.	
Cooperation and participation*	Student was uncooperative and did not complete his/her portion of project.	Student was reasonably cooperative and completed most assigned tasks.	Student was cooperative, completed assigned tasks, and assumed some leadership tasks within group.	Student was cooperative and assumed many leadership tasks within group. Student's contributions exceeded responsibilities to group.	
				Total points	**/24**

*Assigned to individual group members through a combination of peer evaluations and teacher observations.

Although students were not initially enthusiastic about the writing exercise, many were pleasantly surprised by how much they enjoyed creatively assembling stories and concepts. Submissions ranged from factual news reports to humorous editorials to elaborate comic strips. As demonstrated by the quality, vitality, and ingenuity of student work, my chemistry classes clearly enjoyed a memorable and worthwhile learning experience.

Project assessment and extensions

Students were evaluated on the basis of both their group presentations (50%) and individual news stories (50%). Points for group research and presentations were assigned using the scoring rubric in Figure 3. (At the conclusion of the project, students rated fellow group members' contributions in order to better inform my evaluation of the cooperation and participation component.) Individual news stories were assessed using a rubric of a similar style with comparable criteria (content, organization, format/style, and originality/creativity).

Of the 54 students who participated, 87% rated the project as good or excellent through anonymous evaluations. Several students commented that they enjoyed the personal stories behind what could have been a somewhat stale topic. Some reported that exploring the intricacies of a particular experiment or "mind-blowing idea" was challenging and fun. Other students enjoyed wearing costumes, creating PowerPoint presentations, building models, and conversing with their peers. Although costumes should not be required, they may significantly enhance the overall experience of the gathering. Students seemed more apt to "become" their scientists if they were dressed accordingly. Costumes ranged from simple lab coats to wigs and bottle-cap spectacles (see the picture of students on p. 26).

While the project described here is intended for high school chemistry students, it could easily be adapted to fit a lower-level physical-science course. No prior knowledge of atomic structure is required, although teachers may wish to give additional guidance to lower-level students encountering more advanced concepts for the first time. This type of activity could be used to explore the rich history of science in other subject areas, as well. For example, Gregor Mendel might convene a gathering of Franklin, Watson, Crick, McClintock, Pauling, and others who participated in the discovery of the DNA structure and the modern understanding of the genetic code.

Final thoughts

Overall, my experience with this project was overwhelmingly positive. Students impressed me with their animated presentations, their willingness to role-play, and their creative news coverage of the day's events. In the course of our mock gathering, students moved from the simplistic "solar system" model of the atom found in middle school texts (with planetary electrons circling a sunlike nucleus) to a much more sophisticated, realistic model based on experimental evidence gathered by the scientists studied. Moreover, they began to comprehend the difficulties involved in interpreting experimental data, constructing models, and revising these models to coincide with new evidence.

The student-initiated debates that followed Thales' gathering were perhaps the most revealing: How has knowledge of atomic structure changed since Schrödinger's time? What types of experiments are scientists conducting to learn more? Would the current atomic model undergo changes or refinement during their lifetimes? I was thrilled to see students delving beyond a basic textbook understanding of the atom, searching for more answers, and thoughtfully questioning what lies ahead!

From the riveting personal story of Marie Curie to the complex atomic orbitals of Erwin Schrödinger, the knowledge each group gleaned through their independent research afforded a sense of pride and accomplishment. For groups who encountered more difficulties, a deeper appreciation of scientific discovery and process no doubt was achieved. All students seemed to leave the gathering with a heightened awareness of science as a human endeavor—not separate from society but rather an integral part of society. ■

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