

# An Effective Technique for Reading Research Articles— The Japanese KENSHU Method

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A number of recent journal articles are devoted to writing (1), communicating (2 and references therein), teaching techniques (3, 4), and involving students in scientific discussions (5), but few articles have appeared that can help students become familiar with reading scientific literature. Many instructors already include the reading of research articles as part of a student's normal assignments. We would like to propose a method for teaching the reading of research literature that helps a student develop confidence and understanding. It has been used successfully for developing literature skills with high school, undergraduate, and graduate students in the U.S. engineering curriculum. The method, which has the Japanese name KENSHU, was developed by modifying a system used at a top Japanese national university.

KENSHU is Japanese for research understanding. The basic steps of KENSHU are (i) take a recent foreign (English) scientific article and divide it into sections, (ii) read and discuss a single section with a more experienced classmate, (iii) translate the section, (iv) continue step iii until all sections are finished, (v) prepare a one-page summary of the article with key graphs and tables, and (vi) present the findings of the article at a mini-conference.

In this work, we have put into words the aspects of reading a scientific article incorporating the KENSHU framework. We applied the method to U.S. university juniors, seniors, and graduate students as well as junior and senior high school students.

## KENSHU Implementation And Overview

Students have their own individual article to study throughout a given semester or research session. We begin by providing each student with the *first page* of a recent research article and set deadlines for completion of KENSHU guideline steps noted below. We act as a facilitator of information transfer and suggest resources where students can obtain additional information or explanations. The students work in groups (each has a different paper) and follow KENSHU guidelines to develop a final one-page summary of the article and an oral presentation to explain its concepts. We incorporate KENSHU into our courses, which allows us to give students a modern overview of current research in areas such as thermodynamics, phase equilibria, mass transfer, separations, environmental technology, or even specialty areas such as supercritical fluid science. The next few sections describe KENSHU as we have applied it to an undergraduate course such as Chemical Thermodynamics. Although we do not provide a grading scheme here, in our implementation, KENSHU generally accounts for 10% of the final grade, so it is taken seriously.

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## Article Selection

Article selection is very important for success with the KENSHU method. A proper article allows a student to gain confidence in reading, since the course textbook can be used to explain some of the concepts discussed in the paper. Below is a list of basic criteria that we use for KENSHU articles.

### Criteria for KENSHU Article Selection

1. Recent publication (within the past 2 years or so)
2. Experimental results with apparatus
3. Correlation of experimental results with a model
4. Suitable level of difficulty for the student

As these criteria indicate, research articles should be *current* as opposed to *classical* research articles. Current articles emphasize modern research techniques and applications and in general students find them more interesting because they are relevant to current social, economic, or environmental issues. Criteria 2 and 3 ensure that the articles are not too theoretical. Research articles that contain experiments are generally more comprehensible to students just beginning to read the literature because they deal with real physical quantities such as composition, temperature, or pressure. In addition, since experimental research works focus on measurements, the models are frequently fitted to the data rather than developed and therefore are easier to understand, at least in their application. Finally, the level of the article needs to be appropriate for the student. For juniors, we have found articles from experimentally oriented publications such as the ACS publication *Journal of Chemical & Engineering Data* to be suitable. For junior/senior laboratories we have found articles from *Environmental Science & Technology*, *Separation Science & Technology*, *Journal of Supercritical Fluids*, *Chemical Engineering Science*, and others to be appropriate. For graduate thermodynamics, we have found articles in *Fluid Phase Equilibria*, *AIChE Journal*, *Journal of Physical Chemistry*, *JACS*, etc. to be at a suitable level. Although graduate students are capable of reading articles in more advanced journals, it is frequently beneficial in a course to start them with less advanced articles to build confidence. Our experience with high school students has been with those having special projects. For them, appropriate articles report data on the simpler physical properties such as density, viscosity, pressure-volume-temperature, and phase equilibria. In addition to the journals listed above, articles from *Chemical Engineering*, *Journal of Food Technology*, or *Journal of Chemical Education* make suitable reference sources. Retrieval of the articles can be either by the instructor or, preferably, by the student with a university contact. The reading of a true scientific article will greatly develop high school students' writing along with their scientific work because they will see how data and results are reported to the scientific community.

## KENSHU Guidelines

The eight steps in reading and understanding a literature article are listed below. KENSHU is generally performed as part of a normal course or research activity and is therefore a supplemental activity like homework. As such, the instructor sets up a schedule for timely completion of each step and a written narrative is expected for each step.

### KENSHU Guidelines for Reading Scientific Literature

#### A. Preparation

1. Obtain the article from the library.
2. Define the title.
3. Underline all words that you do not understand or cannot explain with a picture.
4. Discuss the title with a group member.
5. Define as many words as possible so that the next tasks are possible. This includes chemical structures, properties, etc.

Suggested references: the dictionary; your textbooks; McGraw-Hill Dictionary of Scientific and Technical Terms; Condensed Chemical Dictionary; Merck Index; Techniques of Chemistry; Kirk-Othmer Encyclopedia; Shreve's Chemical Process Industries.

#### B. Introduction

1. Where was the work conducted? By whom?
2. How many publications did each author have in 1992? Use *Science Citation Index-Source Index*.
3. Who paid for the work? (See Acknowledgments section at end of the paper.)
4. Why is the work important? What are the applications? See Kirk-Othmer Encyclopedia or other references.
5. What is the work related to?
6. Why were the substances chosen?
7. What problem is the author trying to solve? How?
8. What are some approaches that others are taking or have taken? Why can't those methods be used?

#### C. Experiment

1. Draw a diagram of the apparatus.
2. List the pieces of the apparatus.
3. What is the function of each piece?
4. How do you operate the apparatus? (List the steps.)
5. Why is each step necessary?
6. What are the materials used?
7. What is their source and purity?
8. What are the measured variables? How are they measured?
9. What are the controlled variables? How are they controlled?
10. What is the accuracy of each variable?

#### D. Model

1. List the symbols.
2. What do the symbols represent?
3. What variables does the model try to relate? What are the independent and dependent variables?
4. Is there a theoretical basis for the model?
5. If there is a theoretical basis, what is it?
6. Derive the equation. Check the algebra that provides the equation.
7. What are the fitting parameters in the model?
8. What do they represent?
9. What are the constants in the model?
10. What do they represent?

#### E. Verification

1. Replot the author's data.
2. Is all information given? Add more labels if appropriate.
3. Verify that the data in both graphs show the same trend.

4. Replot the model or confirm the equilibrium calculations.
5. Can the model describe the data?
6. Make a residual plot (Calculated values minus experimental values).
7. Are the errors random? Are the errors systematic in some regions? Comment on possible reasons.

#### F. Results and Discussion

1. How does the author demonstrate that the equipment works? (Provides reliable data.)
2. What are the variables in each figure?
3. What relationship does the model predict?
4. Does the model correlate the data?
5. Does the model fit the data over the entire range?
6. Is there scatter in the data? Does the scatter occur only over a certain range? Why?
7. What is the repeatability of the measurements?
8. What are the three most important findings of the author's study?

#### G. Conclusions

1. Did the author solve the problem?
2. What did the author conclude?
3. Is the model a good one? Over what range?
4. How can the experiment be improved?
5. What are the next steps?
6. Are additional experiments necessary?
7. Is a better model needed?

#### H. Presentation

1. Prepare a one-page handout that summarizes the article.
2. Make a photocopy for each person in the class.
3. Provide a 6-minute presentation (maximum of 4 overhead transparencies) with an additional 2 minutes for questions.
4. Suggested time for each topic: Introduction, 1 minute—brief, factual, and with chemical structures; Experiment, 2 minutes; Model and Discussion, 2 minutes; Verification and Conclusions, 1 minute.
5. *Practice!* Several dry runs are necessary for effective communication of the information in the allocated time.
6. *Prepare!* Any questions given in the items above may be asked.

In the Preparation step, students retrieve their individual articles and work with common references to define unfamiliar words, particularly in the title. They write chemical structures, look up physical properties, and try to define words in terms of diagrams. The instructor divides the class into groups and students are encouraged to discuss unfamiliar concepts. Where graduate assistants are available, the student groups can also be assigned to a graduate student. It should be noted that no single instructor or graduate student can be expected to be totally familiar with research concepts presented in 15–30 articles. However, each person can provide insight to understanding some of the concepts in each paper. All persons involved are guaranteed to learn something new.

In the Introduction step, students try to define the purpose of the article, its significance, and applications (sometimes theoretical, sometimes applied), and to identify who paid the money for the research. In addition, they are introduced to *Science Citation Index*, which is important for tracing a researcher's activity. In the Experiment step, students draw diagrams of the apparatus in their paper, which many times requires them to search and look up the information in a previous reference. In the Model step, students list the symbols of the models presented in the paper and attempt to determine

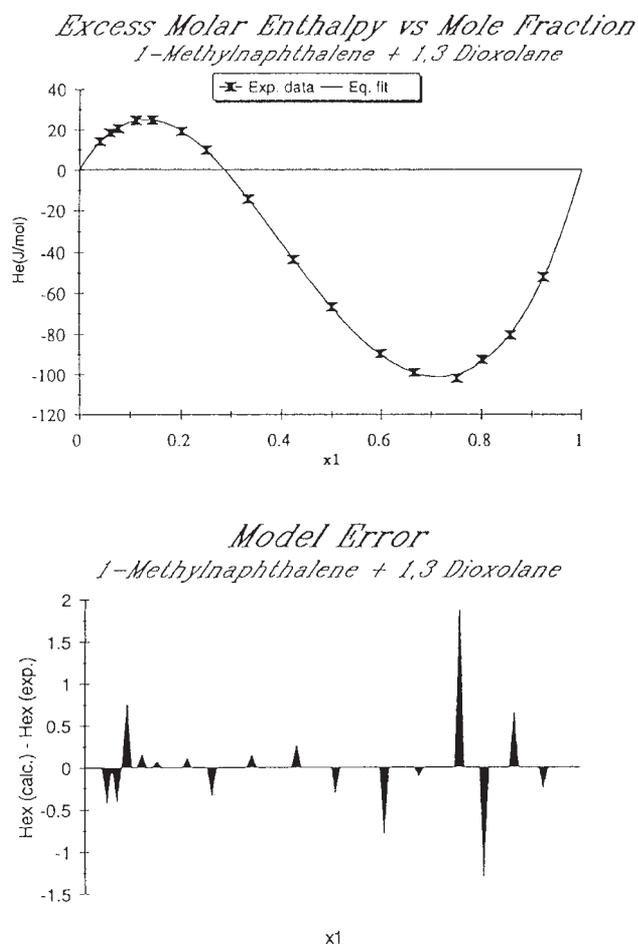


Figure 1. Excess molar enthalpy of 1-methylnaphthalene (component 1) and 1,3-dioxolane with calculated residuals. Data and equations are from ref 6.

their meaning and whether the symbols are completely empirical or have some theoretical basis. As shown in the KENSHU guidelines, the questions posed help to guide the student to seek out relevant points. Where possible, algebraic derivations are performed to confirm existing equations in the paper.

In the Verification step, students produce their own plots of the authors data and often recalculate the authors' model and make comparisons. Figure 1 is an example of a recent student's work based on ref 6. As in part E of the Guidelines, the data were replotted and a residual plot was made to assess the 5-constant Redlich-Kister model reported in the work. Interestingly, for the system shown, model error is approximately random but is greater at the points where  $dH^{ex}/dx_1 = 0$  or where there is a large change in curvature. These points were not noted by the authors but were discovered by the student. Equation constants determined by the student were

within round-off precision of the data and compared well with those reported in the paper. However in this case, the student found several typographical errors including an incorrectly labeled curve in the figure and an error in the conclusion—1,2-dimethoxyethane was stated as having only positive  $H^{ex}$ , whereas only the dimethoxymethane system had positive  $H^{ex}$ . All of these points were found in the final steps of KENSHU and could be easily overlooked with a quick reading.

Especially in the Verification step, instructor creativity is required in suggesting to students how to verify literature calculations. For the case just given the computations are relatively simple, including the multiple linear regression of the data. For calculations such as liquid-liquid equilibria with UNIQUAC, lattice models, or other models, the calculations may require a significant effort that may not be possible in the given time frame. In this case, we have simply had students confirm that the component fugacities were equal (i.e., calculation of activity coefficient in each phase with calculation data given by the authors) or compare results with other theory where programs were available. In any case, the KENSHU guidelines should not be taken as absolute and rigid, but as a set of guidelines that can be adjusted by the instructor.

The final one-page summary consists of the article title, authors, literature citation, tables, figures, and sections such as objective, experimental apparatus, results, analysis, and conclusion, suitably summarized. Figures are reduced to be as small as possible while maintaining legibility. The one-page handout is distributed to students at presentation time and allows them to have a much greater overview of recent work in chemical thermodynamics than is possible from one instructor. Samples are available from the corresponding author.

## Conclusions

The proposed KENSHU guidelines work effectively and have been used in many courses and research mentorships. KENSHU provides a clear method for developing a student's literature skills. The method provides step-by-step questions that guide the student to search for relevant points. Furthermore, the KENSHU serves as an excellent starting point for items to address when writing scientific articles!

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