



Educational Practices of Sommerfeld School and Its Implications: What is a Good Science Education?

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Introduction

- **What is a good science education?**
- It may be impossible to find an 'absolute' good science education because aims or images of good science education are perceived differently.
- However, we think a good science education can be determined by considering an education that grown-up people would regard as good when they look back on their education.
- If education aims essentially at helping a student throughout his/her life, educational achievement should be assessed over the student's lifetime, not merely based on a test.
- Therefore, we tried to infer good science education from a historical success in science education: Sommerfeld school's case.
- This past science education which has been valuable to many people can inspire modern science educators.
- We used relevant literature of Sommerfeld, disciples, colleagues, and historian for the analysis (Born, 1952; Eckert, 2013; Heisenberg, 1989; Seth, 2010; Sommerfeld, 1949).
- The research questions are as follows:
Q1) What were the educational practices of Sommerfeld school?
Q2) What were the features of the educational practices?

Who is Sommerfeld?

- Arnold Sommerfeld (1868~1951).
- One of the pioneers in quantum physics in early 20th century.
- Professor at the University of Munich (1906~1939).
- Proficient in overall fields of mathematics and a large range of sciences.
- Nominated 84 times as Nobel prize nominee, but never won.
- Four of his PhD students (Heisenberg, Pauli, Debye, and Bethe) and three of postdoctoral researchers (Pauling, Rabi, and Laue) won the Nobel Prize.
- Received Oersted Medal for his outstanding educational achievements in physics (1949).

Educational Practices of Sommerfeld School

- 1) Lecture**
 - Lectures were confined to classical physics.
 - There was no attendance scores, timed tests, or ranking.
 - Sommerfeld emphasized on concrete problems rather than principle.
 - There was intellectually coherent by overlapping contents.
- 2) Seminar**
 - At first, seminar was problem-solving session.
 - After World War I, it was transformed into a meeting for paper review or paper development.
- 3) Colloquium**
 - Colloquium was a regular meeting covering various physics topic.
 - Senior students independently established it for helping junior students to understand modern physics problems.
 - Sommerfeld wanted to participate in it, but students denied.
- 4) Seminary**
 - Seminary was a regular semi-formal meeting of doctoral students.
 - They formed it to share and to discuss physics-related news.
- 5) Out-of-class education**
 - "Personal instruction" from Sommerfeld.
 - After having social time such as lunch, dinner, house party, hiking, and skiing, Sommerfeld and his students discussed physics problems.

Features of Educational Practices

1) Pleasant relationship between teacher and students

- Science education has been considered highly authoritative (Warwick & Kaiser, 2005).
- However, disobeying is necessary for become a researcher pursuing his own thought (Seth, 2010).
- Sommerfeld was willing to display his ignorance and never showed an authoritative manner in scientific discussion (Kirkpatrick 1949).
- Free discussion atmosphere based on mutual trust can serve as a basis for creativity (Runco, 2014).

2) Specific and challenging problem-centered education

- Simply knowing a theory made up of formal propositions does not mean knowing science (Polanyi, 2009).
- Practiced skills and techniques in normal science are essential for doing improved and progressive research if education does not make students only perform what they have been taught (Kuhn, 1977; Warwick & Kaiser, 2005).
- Also, problem-centered (or subject-centered) education can be an alternative of teacher- or student-centered education. "To tell of not to tell?" dilemma from the two extremes is common in science education (Wallace et al., 2002a; 2002b).
- Debye sometimes complained about the fact that Sommerfeld had not taught physical principles (Seth, 2010) but, ironically, he won the Nobel Prize.

3) Intellectual coherence on various topics

- Sommerfeld pursued intellectual coherence on various topics.
- The effort of Sommerfeld is valuable in that it enabled his students to do coherent scientific activities on the huge and agreed basis of science (Chang, 2007).
- Also, the connectivity of topics is important in that it can lead to divergent thinking (Shawyer, 2003).

4) Pursuit of shared answer

- There were lengthy discussions between Sommerfeld and his students about physics problems (within the school).
- Also, opinions and students were frequently exchanged between Munich, Copenhagen, Göttingen, and Leiden (across schools) (José, 2011).
- Sommerfeld school created a culture of interaction in scientific education, and students could experience real science as a community.

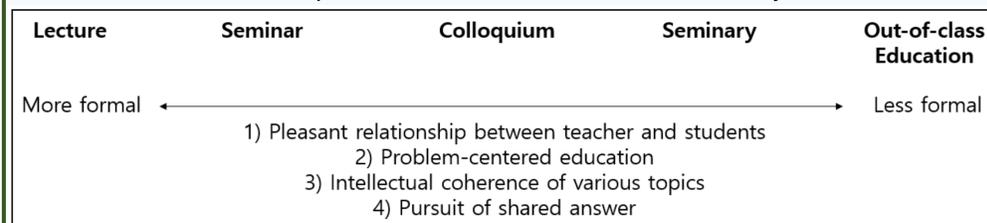


Figure 1. Features of educational practices in Sommerfeld school

Conclusion

- If a case of science education is highly appreciated by disciples and modern men, it can be regarded as "good."
- Sommerfeld school as the case of good science education implies the followings in science education.
 - 1) Free atmosphere rather than authoritative atmosphere.
 - 2) Subject-centered education rather than teacher- or student-centered education.
 - 3) Connection and expansion rather than focusing on only one specific topic.
 - 4) Social consensus rather than personal constructivism.

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