Large Context Problems and Their Applications to Education: Some Contemporary Examples

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ABSTRACT: Some 35 years ago, Gerard K. O'Neill used the large context of space travel with his undergraduate physics students. A Canadian physics teacher, Art Stinner, independently arrived at a similar notion in a more limited but, therefore, more generally useful sense, which he referred to as the "large context problem" approach. At a slightly earlier time the large context problem type of approach had already been used in the study of medicine, pioneered by McMaster Medical School. And the Faculty of Education at the University of Calgary currently uses a large context problem method to deliver its entire curriculum. These approaches are four distinct ways of presenting large context problems to students.

This paper will discuss these approaches historically, look at their grounds and their applications, weigh their successes and characterize their limitations. It will try to see what they take most deeply for granted as viable approaches to teaching science, both theoretical and applied. Finally, it will relate these approaches to the constructivist prejudices of our own time, suggesting their relation to earlier forms of philosophical idealism.

KEYWORDS: Large context problems, large context approach, problem-based learning, contextual learning.

Gerard K. O'Neill has been described by Freeman Dyson, a splendid scientific generalist at the Institute for Advanced Study in Princeton, as one of "two great men [to whom] I was privileged to be a close friend" (Dyson, 1993) – the other was Richard Feynman. When Gerry O'Neill began teaching at Princeton in the middle 1950s, Sputnik had not yet flown. But, after 1957, the United States was under tremendous pressure to catch up with the Russians, not only for reasons of prestige, but because control of space meant control of the world, militarily. In only a decade the United States, under President Kennedy's initial leadership and large budget allocations, managed to land astronauts on the moon and return. While all this was going on, O'Neill was doing

first-rate work in the containment of plasma by magnetic fields and the theory of injecting particles into them. In spite of his general interest in space science-related topics, O'Neill did not, himself, get directly involved in space science until he had to teach first-year physics at Princeton to large numbers of students – Physics 103, in the early 1970s – as a quid pro quo so he could go off to work in California on his magnetic containment problems.

Prior to O'Neill's teaching of Physics 103, the problems which were studied by the students were the typical "out of context" problems, or perhaps, at best, limited context problems. (A projectile is sent upward at 45° to the horizontal with a velocity of x metres per second. Calculate the distance the projectile travels assuming normal gravity and no air resistance). O'Neill found that when he introduced the various necessary parts of elementary physics via graduated problems in space science, he could engage his students' interest and organize problems in a graded way so their knowledge of physics became much deeper.

With a smaller group of advanced students taking the same course, he directly engaged them in problems, taking for granted the enormous complexity – the large context – of practical physics problems relating to getting into space. In fact, he made only one problem the basis for his advanced seminar, namely, "What is the best way for us to populate space?" This is a large context problem in physics, but it is also a large context problem involving many other sciences and proto-sciences, as well as implying problems in human culture and organization, from art and architecture to medicine, social welfare, education, and recreation.

In order to answer the large context problem one has to pose many other subordinate problems and answer each of these in turn. Indeed, they may all have to be answered before one can have a plausible answer to the main question or problem, itself. For example, the question suggests that there may be more than merely colonizing the moon or an asteroid or another planet as a means to colonize space. So, the first thing of which one has to conceive is whether or not there are any possible alternatives, for example, "Could one live in space indefinitely on a space ship or on a space ship writ large, say, a space station, and, if so, what would such a space station look like?" "Would a colony on such a space station have advantages over a colony on the moon or an asteroid?" "Are there many possible solutions to its design or are there a very limited few?" "What minimum or maximum size might it have?" "How earth-like might it be?" "How would its design differ from the design of a colony on an asteroid or the moon?" "What does one mean by design, here?" "Are we only interested in the physics

of constructing a space colony or are we interested, as well, in the broadly understood human environment in all its variety of aspects and details?”

Now, you can see that the questions multiply very rapidly, here, and, in O'Neill's case, they did so multiply, and he and his students, using elementary physics and elementary considerations from other disciplines, attempted to answer most of them in the advanced section of his Physics 103 seminar. There is a suggestion by Freeman Dyson (1993), a close friend of O'Neill, in his celebration of O'Neill's life and work, that O'Neill's reorganization of Physics 103 remains at Princeton to this day. In particular, the *Princeton Learning Guides* are supposed to follow directly from O'Neill's influence. That may be so, but I can see hardly any use of serious large context problems in the present-day version of that course, which can be read entirely on the web. There are some difficult problems, to be sure, with a lot of help in the guides, but there are none of the problems mentioned by O'Neill in his books, *The High Frontier* (1977) and *2081* (1981), which he worked through with his advanced seminar. The problems in today's Princeton learning guides are all the standard problems you could find in any textbook. The gradation of the difficulty of the problems is also similar, and there is no sense in which a very large context is the vehicle from which students are to generate and solve a host of problems that arise when one tries to answer a seriously large-scale problem like “Is colonizing the moon or an asteroid the best way for us to populate space?” So, we depend on O'Neill's account of what he was up to in that seminar and in his subsequent work to see his characterization and treatment of such problems. O'Neill, subsequently, became a consultant to NASA on space colonies and on techniques for approaching space, a widespread lecturer, and public figure, and founded an organization to further his approaches to large context problems relating to space.

Art Stinner's large context problems have a slightly different cast from those of O'Neill and were devised originally for use in his physics classroom. Although Stinner remarked to me in the early 1970s that he had been inspired by O'Neill, he deviated from O'Neill's conception in a number of ways. (In fact, his recollection now is that he worked quite independently of O'Neill and only subsequently discovered him as a fellow traveller). In particular, while Stinner retains a wide context for his problems, they are not as wide as those of O'Neill. Nor is Stinner interested in using any manner of science necessary to handle his problems. He is interested in physics. So, his large context problems are circumscribed by that interest entirely.

One of Stinner's early major efforts in this direction and, perhaps, typical of his work, was inspired by the Second World War movie, *Dambusters*, in which a team of inventive Englishmen attempt to find a way to break a crucial German dam or complex of dams on the Ruhr river. Stinner reconstructed for his students the physics of busting the dam, specifying a variety of problems which have to be solved in order to land an explosive drum, bouncing along the water, such that its repeated skip distance enables it to hit the dam and blow it up. He subsequently published this problem collection in a British science education journal (Stinner, 1989) to great popular acclaim. Although the context of Stinner's early efforts is less expansive than that of O'Neill, there is a similarity in that, again, a large number of questions have to be asked and answered before the main question, namely, "Can we devise a scheme actually to blow up the dam?" can be answered. Perhaps, we should call Stinner's problems medium context problems, though I think the actual terminology large context problems is his, not O'Neill's. Or, perhaps, we should refer to O'Neill's problems as vast context problems.

Another of Stinner's early major efforts was to tackle the physics of *Star Trek* and in this he recruited me to join him in collaboration (Stinner & Winchester, 1981). We primarily asked the question: "Given contemporary physics, what sense can we make of faster than light travel for a space ship?" Again, a large number of intermediate questions arise, including "Does contemporary physics permit faster than light travel, and if so, what does it imply for physical objects like a space ship?" "If contemporary physics does not permit faster than light travel, why not?" "Even if we did not have motion approaching the speed of light, what are the implications for star travel at less than light speeds?" and finally, "What does such travel imply for payload, for example?"

Subsequently, following the Stinner-Winchester article published in a bumper Christmas issue of *The New Scientist*, an entire book has been written on the physics of *Star Trek* by an American physicist (Krauss, 1996), the bits of which could be considered components of a large context problem, or, at least, a medium context problem. Interestingly, this latter work was written in complete ignorance of our earlier work. Stinner, subsequently, developed many such problems, some of which he has incorporated into a manuscript for a book that will, I trust, be published in the near future.

Happily, Stinner's students have also been interested in his sorts of problems, though not always in his way. To take one prominent example, Stephen Klassen looked at the physics of the first transatlantic cable as a doctoral thesis project, a large context problem which much occupied Lord Kelvin and a number of his distinguished contemporaries (Klassen, 2002). In doing so, he has developed a variant on Stinner's themes. In particular, Klassen is interested in the interaction between history and physics to help provide a learning context for students.

Let me summarize what I have presented so far. O'Neill's concern was to specify problems of vast context of gripping near future importance, such that the answers to the problems were not known in advance but could be tackled to the extent possible by present day physics and technology. Stinner's concern was either: (a) to pick contexts in which one might develop known physics to solve the problems that necessarily arise or actually arose in that context (such as in the case of *Dambusters*); or (b) to show how known physics might relate to the context of a speculative situation as *Star Trek*, or travel to or between asteroids, or the impact of a meteorite on the earth or the moon and the like. Klassen is interested in the actual interaction between history and physics as a learning context for students, especially in historical contexts of great breadth and depth. Stinner's latest ventures, namely the writing of manuscripts illustrating imaginary dialogues between great scientists surrounding topics like "the age of the earth" or the scientific and social life of great international figures like Count Rumford, suggest that his interest has moved definitely towards the historical, perhaps inspired by, perhaps inspiring, the work of Klassen.

Medicine has also provided us with examples of the large context problem approach. The approach to education in medicine followed by a Canadian institution, McMaster Medical School, on its founding in 1966, was to teach medicine in context, always bringing in the patient and the larger social and family context in which a patient finds herself or himself. A patient is usually in a family setting, comes from a particular social, religious, linguistic, ethnic, or educational background. A patient has a complex history which is more than the history of the disease process or processes which the patient or his family have previously suffered, about which histories in medicine are characteristically taken. Also, as the recent SARS, mad cow, and West Nile Virus outbreaks in Canada suggest, the context of a disease process may be very large and goes beyond the treatment and, perhaps, cure of an individual patient.

At McMaster, when a patient is not necessarily available to illustrate a particularly important medical context, actors are hired to portray the patient and to answer as she or he might have done in the given large scale context of a patient's life. So, the task of the future physician becomes one of filling in the large background context of the particular patient suffering from particular symptoms so that diagnosis and treatment can be made in the largest possible context, and the patient is the centre of that context. Of course, the entire spectrum of science and technology may be involved in any given case. And, here physics, chemistry, biochemistry, and a host of special technologies may be relevant, such as DNA analysis, X-ray tomography, ultrasound, or magnetic resonance imaging.

For example, a patient might show up in emergency with *difficulty breathing*. The task for the student is to ask a complex set of questions, assuming this is a large context problem, and to engage in a series of investigations until what lies behind the breathing difficulties might be determined. These might include determining whether the patient has ever had breathing difficulties before. Has the patient a history of asthma? Has the patient ever been treated for it? Has the patient just moved house or changed residence or recently come to town or gotten any new pets or taken up new activities like riding horses? Or has the patient an occupation that requires, for example, a lot of flying? And does the patient travel by air a lot, sleeping on the plane, and if so, has the patient any leg pain, particularly in the calf region? Has the patient a family? Is the family context helpful and restful, or does it provide a lot of stress in the patient's life? Has the patient any new friends or lovers? Has the patient been in any accidents lately, perhaps automobile accidents? Is the patient in any difficulty with the law? Or are any of her or his family in such difficulty? And so on. The elimination of irrelevant context is crucial here, as is identification of appropriate context, but the physician begins from the widest possible context in order to be sufficiently comprehensive in the first instance.

When a case is actually worked up, it may resemble something of a complexity rivalling O'Neill's space station or, at least, the complexity of getting a mass driver up and running. At McMaster, the study of organ systems forms the basis both of the fundamental sciences underlying the study of disease processes in the human context and the study of the pathology relating to those organ systems. But it is always remembered that it is an individual human being with her or his social, psychological, cultural, ethnic, religious, and personal historical context in which the disease processes are studied. Knowing neither of O'Neill

nor Stinner's work, since they actually anticipated it, the faculty at McMaster referred to their approach as that of problem-based learning, but clearly, the problems used were of the large context kind. As John Evans, the school's first dean, remarked to me: "We backed into it. We knew we wanted to teach in an entirely new way, but we had no idea what that was to be other than it would not be the old 'lecture to a 100 students' method."

Finally, the Master of Teaching (MT) program at the University of Calgary is a program consciously designed to produce professional teachers, initiated by myself while Dean in 1994, implemented in 1995, and strongly influenced by the contextual education of McMaster Medical School. Also, at an early stage, Art Stinner was invited to come to the faculty and talk about his own large context problems, with a view to suggesting to the prototype writing team for the MT program some of the ways in which one might approach professional education, using a problem-based approach that presupposes the study of the largest possible educational context. While Art Stinner's examples tend usually to come from physics, the possible analogies are always there. As the dean initiating the new approach, I hoped that my faculty would see the relevance of the kind of work Art Stinner was doing in Winnipeg, especially in relation to their understanding of what had been done in McMaster.

Themes, such as learners and learning, teachers and teaching, and curriculum context, as well as praxis and integration, were used by the prototype team to be the analog of McMaster's organ systems. All of these themes are studied in the MT program from this large context vantage point. So are ethical questions, which in education are comparable to, and equally as difficult as, those faced in medicine. Also, the study of curriculum follows a case-based approach in which the complex context of the curricular material to be learned and taught is approached. At the beginning of the program, the large context problems which make up the cases are potted, in the sense that the students are given fairly explicit instructions on how to proceed to tackle their cases. They are even supplied with exemplary initial readings from a variety of sources. But they are not supposed to stop there. They are supposed to develop their cases in their own way, finding new problems not identified in the initial materials and, perhaps, investigate such problems. Thus, a graduate of this program should be able, better than the next teacher, to identify complex educational contexts and educational problems or learning difficulties, and to diagnose what is wrong, and to offer plausible solutions to such

learning difficulties or educational problems which may be faced by a student or an entire class or sub group in a class of learners.

Let me illustrate what is intended in the Calgary MT program by examples of such problems offered in the first and last terms of the program. First, I will give one of the early potted problems and then I will give one of the students' own problems which is to integrate everything they know and to offer solutions as best they can in the final term.

An example of the former is a case called "Understanding the Difference Diversity Makes: A Case of Differences and Diversity in Learning and Learners." In this case, a preamble explains that school populations have never been as diverse as now and that schools are expected to meet the needs of a population that is racially, culturally, and linguistically diverse; to confront gender, racial, and economic disparity and discrimination, and to create classrooms in which there is mutual respect and social harmony. A variety of key concepts are noted, including bias and stereotyping, physical appearance, physical and mental health, intelligence, cultural background, race, ethnicity, socioeconomic influences, community influences, emotional factors, self esteem, motivational factors, and the like. Then, a case narrative is given which attempts to present a genuine setting in a school in which these concerns and factors come into play. It is presented as a complex, multi-layered, or large context problem, and, of course, a curriculum setting is presupposed in the presentation of such a case. As well, relevant readings are suggested by authors from Canada and the English-speaking world, more generally. Finally, a task is specified in relation to the large context problem presented and the student is expected to respond by researching, thinking, and writing.

At the end of the program, none of the material is presented to the student. Instead, a topic is introduced with an ethical twist and the student is to develop her or his own large context problem in the form of a case study, with its own questions, problems, and suggested approaches or solutions. One of the ways in which I approached such question with my own final term ethics class was to have the students respond to various aspects of the "Socratic Oath" with which all of our students are acquainted. For example, one of the sub-pledges in the Socratic Oath is this:

If I am unable to carry out my teaching responsibilities with competence and integrity, then I shall summon the courage to leave teaching to others.

Another is:

I shall never use the power of my position as teacher for my own personal advantage or to the disadvantage of others.

And, another is:

I shall encourage a lifelong love of learning, of wisdom, of texts, and of thought.

My students were asked, each week, to suggest moral dilemmas which an ordinary teacher might face surrounding each of these, illustrating them with actual classroom situations or plausible student, parent, or colleague responses. Then, they were to discuss, attempt to understand, and, if possible, resolve their moral dilemmas

These approaches, the O'Neill, the Stinner, the McMaster, and the MT Program approaches, seem to me to be four distinct ways of presenting large context problems to students. All of them could be used in the working through of scientific material for learning. All of them emphasize different notions of context, of problem context. All of them look like they might be helpful for this or that student, or this or that group of students, at this or that time. None of them looks like a general solution to the problems which educators face when teaching natural science, mathematics, the humanities, the social sciences, the medical sciences, the arts, or about teaching, itself.

They have in common certain assumptions about learning. In particular, they all presuppose:

- 1) That learning is best done when learning is not isolated from a whole background of notions, especially notions which are relevant or exciting and which provide myriads of possible problems which may have to be solved before the main question or questions can be solved. These notions may be future-oriented, historically-oriented, or immediate patient- or student-oriented.

They all presuppose:

- 2) That we probably learn better when our peers are working with us on things too grand for the individual to work on entirely on her or his own, even when bits and pieces of our work must probably be done alone.

They all presuppose:

- 3) That certain large problem contexts (especially global task-oriented contexts, like how do we best build a space colony or how do we construct an entirely different and better kind of medical education) are more intrinsically interesting than out-of-context problems, and many subordinate problems in such contexts are naturally treated

by us as more interesting than if they had been presented as individual, isolated problems.

Are these presuppositions plausible for the large context games now being humanly played? I think they are. This does not mean that we could not devise educational research to help us determine whether or not they really are as plausible as we take them to be, or whether there are other equally plausible ways to bring about deep, relevant, and non-fragile learning.

The large context approach is sometimes seen, by those with a constructivist view in mind, as a plausible ally, indeed as a very strong version of the constructivist approach. Remember that the constructivist approach does not think that a scientist actually discovers anything, but, in a very human sort of way, makes it, builds it up, or constructs it. Thus, science for such a thinker is a human enterprise all the way through. There is nothing simply out there to be found. There is only what we make of what is out there. And, so, what is out there and what we make of it cannot be separated, in the end. Thus, our imagination, both theoretical and practical, is essentially involved in the human enterprise of science. Indeed, for someone with this view the objects of science – the particles, the laws, and so forth – are in the head of a scientist; they are creations of her or his imagination, albeit constrained in certain ways by the possibilities of our sensing or measuring or extending our senses for observational purposes.

Now, when one takes a sociological turn and thinks of the constructions of science as social constructions, either for the furtherance of science itself or for its practical uses, one presumes that science is essentially an enterprise involving many human heads and hands. But whether one is thinking of science as an individual or social enterprise, it remains a species of idealism, not realism. For a realist, the theories of science are, at least, attempts at approaching the truth, if not the truth itself, and scientific theories are assumed to mirror the world. Truth, for a realist like, say, Russell or Rom Harré, is a result of the conformity between one's theories and reality, but for an idealist, whether the Kantian, Bradleyian, or Collingwoodian kind, there can be no possible conformity between one's theories and the world, between theory and reality, for the only reality is the reality shaped by our thought and actions, individually or collectively, or both. That is to say, essentially the world is a world which is produced by our imagination, not one simply found in nature, and that is as true of the aspect of the world which we inhabit that we call science as that aspect which we refer to as art, or for that matter, religion.

If constructivism is a species of philosophical idealism, as it certainly appears to be, and if the large context problem approach is a strong version of constructivism in action, then does that necessarily make those following such an approach philosophical idealists? Well, the logic of the situation inclines me to think that they must be. Yet, my knowledge of those actually working in such contexts suggests to me that at least O'Neill, Stinner, Klassen, and those at McMaster Medical School, think of themselves as philosophical realists. Only the Calgary MT program has largely and clearly been drafted by those with a definitely idealist bent. So, I am also inclined to think that the large context adherents are not necessarily, in their own hearts, idealists. But if one looks at what they are saying and doing, perhaps, they are.

Or else what they are doing should not be assimilated to constructivist thought at all.

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REFERENCES

- Dyson, F.J. (1993). The life of Gerard K. O'Neill. *Physics Today*, 46.
- Klassen, J.S. (2002). *A theoretical framework for the incorporation of history in science education*. (Doctoral dissertation, University of Manitoba, 2002). Dissertation Abstracts International 64(06), 2031.
- Krauss, L.J. (1996). *The physics of Star Trek*. New York: HarperCollins.
- O'Neill, G.K. (1977). *The high frontier*. New York: William Morrow & Company.
- O'Neill, G.K. (1981). *2081: A hopeful view of the human frontier*. New York: Simon & Schuster.
- Stinner, A. (1989). Physics and the Dambusters. *Physics Education*, 24(5), 260-267.
- Stinner, A. & Winchester, I. (1981). The physics of Star Trek. *New Scientist*, 92(1285/1286), 884-888.