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PARADOXES OF "CONSTRUCTIVIST TEACHING" AND THEIR IMPLICATIONS FOR TEACHER EDUCATION

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ABSTRACT

The implications of constructivist epistemology and conceptual-change ideas have received less attention in teacher education than in the case of teaching science to pupils. However, some paradoxes mentioned in the literature apply to teacher education in special ways:
1. Even if we accept the validity of a constructivist epistemology, does that imply a specific teaching strategy?
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INTRODUCTION

It was proposed by Kempa (1983), that learning theories, if they are to have any place in the education of teachers, must be useful and applicable to the enterprise: they must provide a framework for interpreting learning situations, and point the way to some instructional decisions. Neither constructivism nor conceptual-change ideas are exactly

learning theories as he thought of them (although Piaget's was one of the theories mentioned), but I find his general argument worth keeping in mind, and as well his cautionary note to not try to apply uncritically what the current literature is touting. In this spirit I want to highlight a couple of areas of concern to me at the overlap of constructivism, conceptual change theory, and teacher education, and explore a little how they might affect the education of teachers of science.

I want to emphasize that the "paradoxes" in the title do not refer to constructivism per se. Whatever its current status among philosophers, it is a perspective that has lately found great and widespread appeal among educators - and not just educational researchers - at least at a verbal level. One can speculate that this is an example of the conceptual change model of Strike & Posner (1982) in operation. Two of the conditions proposed by them as required for conceptual change are met: there is general dissatisfaction with the previously prevailing view of learning as reception of transmitted knowledge; and the central idea of constructivism is at least intelligible. As for the other two conditions - plausibility and utility - the verdict among educational practitioners is not nearly so clear. That may account for the frequently superficial acceptance until now of the idea of constructivism.

Since the topic of this meeting is misconceptions, I also want to connect constructivism with that label, or with its more up-to-date description - the formation, modification, and sometimes wholesale change of conceptions. There are no "official" definitions of either constructivism or conceptual-change theory (despite an assertion to the contrary in the gratuitously vitriolic attack by Suchting, 1992, on the "doctrine" of constructivism), as indeed there should not be. Both are built around some shared general

ideas, and it seems that there is a large overlap between sets of people who find each of them fruitful. It is possible, in principle, to imagine instances of one without the other. Mutukrishna et al. (1993) claim to have succeeded in teaching certain concepts in astronomy without any reference to students' preconceptions. They blame previous failure on inadequate curriculum design, though that is difficult to evaluate since the comparison is with a film (*A Private Universe)* rather than a research study. Cleminson (1990) goes into great detail to argue that constructivism and conceptual-change theory are in effect analogues - the one philosophical, the other psychological - with nearly complete correspondence in their assumptions and assertions. Bell (1993) refers to a "constructivist and conceptual-change model of learning," implying that they are practically identical. Driver (1989) places conceptual change within the realm of constructivist epistemology. I should add here that this discussion is about constructivism ***without*** the adjective "radical" (von Glasersfeld, 1989), hence involving arguments only about the nature of learning, not about ontological reality. For the purposes of this paper, we do not need to consider radical constructivism. "Trivial" constructivism is sufficient. I find it not at all trivial.

CONSTRUCTIVIST LEARNING AND CONSTRUCTIVIST TEACHING

Is it possible to go from a constructivist epistemology to a constructivist way to teach? Millar (1989) asserts that there is no single path, no one-to-one correspondence. A learning theory is not the same as a teaching theory. Yet the literature is replete with recipes. When I look at the ingredients of varius versions of "constructivist teaching," I find many of them sensible and laudable, but not directly connected to a constructivist epistemology. As Hewson & Thorley (1989) point out for the parallel case of the Conceptual Change Model (Posner et al., 1982), many

instructional schemes purport to implement it, but few are specifically linked to the model. One can support the strategies on general philosophical or educational grounds, but they are not implementations of the model. Conversely, some approaches denigrated as being "traditional" are not incompatible with a constructivist view of learning (Ernest, 1993).

"WHAT IF THEY DON'T CONSTRUCT THE CONCEPTION I WANT?"

This is a problem that's frequently finessed. In one form or another, the key point of conceptual-change strategies is almost invariably to encourage students to revise their conceptions "in the direction of conceptions held by scientists," (Neale et al., 1991), so that students "... will see the scientific viewpoint as more ... fruitful than their own." (Bell, 1993, p. 31) I don't want to discount the efforts of good teachers and researchers in trying to reconcile their philosophical ideas with the vagaries of human behavior, and I don't want to pretend that there is an obvious solution. Confrey (1990) states the issue clearly: "Teachers ... must be prepared for the likelihood that the students' constructions will not coincide with their own ..." (p. 112).

SCIENCE EDUCATION AND TEACHER EDUCATION

The dilemmas for teacher education are similar to those of science education for younger learners. Teachers - both preservice and inservice - arrive with more or less well-articulated ideas about learning and teaching, much as students of science arrive with preconceptions. Just as learning in science depends on what the learner already knows or believes (Osborne & Freyberg, 1985), so what teachers know, the beliefs to which they assimilate their new experiences, strongly affect what they make of these experiences. Learning science and learning to become a (better) teacher both involve conceptual change, sometimes radical change.

Do constructivist principles point to specific strategies in teacher education? Should our hopes that teachers develop conceptions of learning and teaching in line with our ideas dominate over our wishes that they develop their own ideas? What do we "tell" teachers, and how do we

"tell" them? How important is it that we model our own advice? Is there a risk of undercutting the message by the way we present it?

IS THERE A "CONSTRUCTIVIST TEACHING?"

I find Millar's (1989) assertion that a constructivist epistemology does not logically entail any specific teaching strategy quite persuasive. That does not mean that any strategy is as good as any other, or that the traditional ways of teaching should be left unquestioned. However, I do want to argue that some tried-and-true techniques take on new significance: we may get a different perspective on why they are tried-and-true.

While I do not offer general solutions to the dilemmas I pose, I wish to call attention to an argument which is part of my personal construction of constructivism. Not only do we, each of us, actively construct or reconstruct our knowledge, but we do so ***all the time***, whether we are beneficiaries of "constructivist teaching" or not. "Learning is taking place at all times in all circumstances for every person" is a layperson's version (Fulghum, 1990, who learned it all in kindergarten). It is not a question of ***teaching*** students to construct. As Greeno (1986) said in the related context of teaching students to think, they know how to think; we have to stop teaching them **not** to think in school, and give them opportunities to practice and develop their thinking muscles. If I am right about this point, or rather if teachers find it persuasive, then teaching is relieved of the responsibility to "get" students to construct and can concentrate on **what** it is that students construct.

According to von Glasersfeld (1993), constructivism does not tell teachers what to do but can point out things **not** to do. Borrowing from Greeno, one thing we should not do is get in the way of students' constructing. This is not a plea for laissez-faire teaching built on a romantic model of development (Kohlberg & Mayer, 1972) unfettered by outside interference. (I wish to note that Kohlberg and Mayer did not advocate such teaching, they merely described it and gave

it a label.) On the simplest level, allowing students to construct means giving them time and mental space and a supportive environment in which to construct.

On a very small scale the recognition and use of "wait time" (Rowe, 1974), by now a standard, tried-and-true part of teacher education, is an example: it involves both time and the freedom from demand to attend too soon and too often to a new sensory input from the teacher. It makes possible, for at least a few seconds, uninterrupted construction of one small part of one's conceptual edifice. In its small way, it is a step against the machine-gun cadence of question-answer of so many classrooms. Millar (1989) identifies "pacing" as one of the areas in which constructivist epistemology has a role to play in instruction, and perhaps this is what he has in mind.

On a larger scale, looked at from the perspective that students **always** construct, the much-maligned lecture may not be so bad. The lecturer speaks, but the listener constructs. If the lecture (or any didactic presentation) is well prepared, **appropriately paced**, and invites overt or covert participation on the listener's part, it can legitimately take its place on the list of "constructivist" teaching tools. So also can the almost-as-traditional (since it only goes back to Gutenberg) print material, which has the advantage that the pacing is in control of the learner. Both of these, however, carry a serious limitation for young learners: children's inability to be physically still for any length of time, when one can practically **see** the juices of life rushing inside their bodies.

If it is true that students are always engaged in construction, one still needs to ask: **what** are they constructing? Not so much whether they are constructing the ideas the teacher would like them to, but: are they even in

the same universe? "I wonder how I could arrange to talk with that new boy in class?" "How does she get away with talking to the teacher like that?" "How are those kids doing wheelies the length of the playground?" There are an infinite number of things to notice and to work on with one's mind. Absent-mindedness does not mean that one's mind is absent, just that it is absent from where someone else would like it to be. Millar (1989) cites **motivation** as another area where constructivism can be useful. I take that to mean motivation to understand something by one's own efforts, to enjoy the "experience of recognizing the power of [one's] own ideas" (Duckworth, in preface to Fosnot, 1989). An orientation toward constructivism may help teachers increase the time pupils spend **mentally** "on task." Viewed another way, students may choose more of the time to make **their** "task" coincide with the teacher's agenda. Inevitably this would result in more concept formation and more conceptual change.

TO GUIDE (OR NOT), AND HOW TO GUIDE

My students (teachers-to-be and teachers already) never fail to ask, when the occasion arises, how interventionist one should be, and, in particular, whether and when to let a "misconception" persist. I have yet to find an all-purpose answer that I consider satisfactory. The literature is full of instances of "successful" conceptual change (and I confess to having contributed to that literature), but my personal experiences are that achieving it quickly is the exception rather than the rule. My reply to students' questions about this is the not-very-satisfactory "it depends" ... on the nature of the students, on how serious is the mismatch with science, on what is the probability that they will have chances to rethink before it "really" matters.

Confrey (1990), after the quote above about the likelihood of mismatch between students' ideas and the

accepted views, states that teachers must be prepared to negotiate with students a "mutually acceptable alternative." Driver (1983) takes a different view: some students will simply never construct some conceptions necessary for future success, and it is appropriate as well as necessary to forthrightly present some ideas as the official science. This is not necessarily incompatible with constructivist ideas. Driver, in fact, bases her argument on constructivism: students construct from their experiences (no matter how carefully orchestrated by the teacher) all manner of ideas, most of them not in agreement with scientific theory; recognizing this, teachers are required to be explicit about the desired end-state, in effect pushing students toward what they are meant to construct. The students will in any case reconstruct what they are told, resulting in a greater or smaller mismatch, but at least they will have a model. (I have found that frequently references to Driver's book, *The Pupil as Scientist?*, omit the question mark at the end of the title, and have wondered whether this is evidence of an assimilation by some readers to a viewpoint rather different from the one I read into the book.)

After defending them in the previous section, I must mention a serious drawback of lectures: not in effecting conceptual change but in monitoring it. The problem with lectures is not that they prevent construction, but that only the most insightful of lecturers knows what the students are constructing. It is the lecturer, not the students, who is hindered in constructing, through lack of adequate feedback. The classroom becomes a severely limited "learning environment" for teachers (Cobb et al., 1990).

Many of the teaching strategies that incorporate conceptual-change ideas include as a key element extensive time for discussions among students and with the teacher (Driver, 1989; Schultz & Clement, 1990): articulation of

students' conceptions before a topic is taken up, and discussions during and after the lessons. Whatever one thinks such discussion may do for students' learning, they are important sources of information enabling teachers to monitor students' ideas and adjust their teaching accordingly.

Among the "context" variables that influence the extent to which teachers should guide conceptual change, age of the learner is surely an important one. The five-year-old constructing rules for balancing objects is in a very different position from the engineering student learning the rules for calculating the strength of beams; different in ability, and different in goals. Science learning always involves a tension between learning ***how*** and learning ***what***. There is a progressive shift in emphasis from preschool to graduate school. When learning ***how*** results in the desired ***what***, it's easy. Most of the time, one must prioritize and compromise.

TEACHER EDUCATION (REPRISE)

Like young learners of science, teachers are constantly constructing and reconstructing their ideas about learning, teaching, and schooling. Compared to science pupils, teachers give us one reason to be hopeful, and one reason to be cautiously pessimistic. As adults and professionals (or budding professionals), teachers have the ability and the motivation to reflect on their ideas - something pupils are notoriously unable or reluctant to do. On the other hand, teachers assimilate their experiences to beliefs formed over 15 to 50 years of living in schools, either as students, parents, or teachers. They also, like science students, need time to construct; not a few seconds, but ***serious*** time, because the concepts and issues are a lot more complicated. If one is persuaded of the worth of constructivism as an epistemology, one has to agree with Fosnot (1989) that the

conceptual changes required of most teachers are great and involve challenges to long-held beliefs and practices.

A reasonable working definition of conceptual-change teaching is "the organization of situations and ... tasks" (Driver, 1989) to promote a desired end-state. In school science, the end-state is "correct" scientific conceptions. I shall argue that the counterpart in the case of teacher education should not be belief in constructivism, but belief in one's own way of finding out and of reaching (tentative) conclusions. Even if I feel confident that this will lead eventually to a constructivist orientation, "eventually" may be a long time in the future, and the resulting ideas may be tempered or complemented by conceptions of teaching and schooling that prevent the constructivist orientation from being observed in practice all the time.

Along the road to this eventual end-state, is it appropriate to "expose" teachers to parts of constructivist and conceptual-change theories (even if only to help teachers gain a common language), and if so, is it appropriate to do so as early as possible? If not, what situations and tasks can be organized toward the end of at least challenging their preconceptions?

Below, I shall argue for a qualified "yes" answer to the first question, and a "no" to the second. Taking up, however, the third question first, several techniques have been employed. Some of these go back to long before constructivism became a household word on the educational scene.

Construction via another domain. Among tried-and-true methods for teachers of science, few have matched "hands-on workshops" for popularity - if not always for long-term results. They became common in the post-Sputnik heyday

of science curriculum development when the National Science Foundation attempted to promote the dissemination of the products it had funded at a cost of many tens of millions of dollars. Such workshops remain popular to this day. At their best they have offered teachers a sense of enjoyment, a change from sitting and listening with reverence to authorities, opportunity to use skills (especially manual skills) which teachers already possess, and "something to use in class tomorrow." They also have the potential to do more, in ways that are pertinent to constructivism. For many teachers they offer a chance to construct knowledge on their own, in domains where their abilities have long lain dormant and unsuspected, and to self-evaluate their newly-built knowledge. When led by sensitive and thoughtful people, such workshops can be used to help teachers reflect on the processes of coming to know, to feel personally the "high" one can get from such coming to know, and to speculate about what that might mean for young learners. "Hands-on" was unfortunately too often equated with physical activity which, for most children and adults, is an irresistible attraction. It has lately been augmented with "minds-on" learning (Trumbull, 1990); in the case of teachers, the minds should not be primarily on the properties of liquids or the behavior of insects, but on the process of learning itself. This reflective aspect of such workshops is often tacit or subordinated to more immediately-appealing goals. In practice, it often doesn't occur.

Construction of science ideas where it is explicitly a means to another end. The experiences arranged by Duckworth (1986), in which (as one example) the concepts of density and buoyancy were explored by teachers in great detail, are instances where science (or, for that matter, any domain) is used as a vehicle to enable teachers, in a group, to think through aspects of the learning process. From published reports and from my own experience, I am

surprised over and over at how much time such experiences require, yet how deep are the teachers' resulting insights.

Observing students constructing science as a means for learning about learning. Situations in which teachers promote and observe students' learning of science concepts can be thought of as descendants of Piaget's clinical interview method. The original one-on-one method has been expanded to group situations. These can be classrooms (Driver, 1989; Watson & Konicek, 1990), or out-of-school learning environments (Neale et al., 1991). Whatever impact such experiences may have on students' conceptions, they can have profound influences on teachers' conceptions. In all variants of this strategy, focussed attention by teachers on what students say and do is a crucial ingredient. At the least, realization of how limited, halting, and slow pupils' conceptual changes often are constitutes an important lesson for teachers.

The strategies outlined in the last few paragraphs can be thought of as a kind of learning sequence. First teachers learn by investigating their own learning, then the learning of selected others (peers, then students). Individually and through group processes, they use these experiences to reconstruct their conceptions of learning. This is very much an inductive process, and one depending a great deal on teachers' preexisting ideas as well as on their individual styles of interacting with students. All the above strategies have been found to be effective in helping teachers construct and reconstruct; all depend on considerable processing or digestion time. They can't happen overnight, or even in the time frame of a university course. It is more appropriate to speak of teacher development than of teacher education.

Teachers engaged in this construction job must do so in

the context of the bureaucratic, political and social system of schooling. Even novice teachers come to the task with ideas based on years of experience as students. To undertake significant reconstruction, teachers need periods of freedom from the realities of normal school functioning (politics, testing, questions of resources, etc.). They need to rebuild their ideas about learning in a protected environment, much as one plants a seedling inside a chicken-wire cylinder until it is strong enough to withstand predation. We should not pretend such an environment is schoool reality (as universities are sometimes accused of doing), but we should also not denigrate it for not being "real." Just as physics students initially learn dynamics with frictionless air tables (and, increasingly, with computer simulations thereof), just as novices learn to swim in a still pool rather than in heavy ocean surf, so teachers need times when they can concentrate on learning about learning, with the distractions of the real world minimized. Obviously such times are hard to come by; society displays limited tolerance for ivory towers, even if they are beneficial in the longer term. Teachers therefore also need to develop tools (and the motivation) to take advantage of whatever they can get in the way of opportunities for their own learning, on the fly, in normal classroom routine, even if these opportunities sometimes come in bits of a few seconds or minutes, and ways to increase the number and duration of these precious periods.

All the above strategies can be considered ways to develop "teacher/researchers," a dual role advocated by Piaget many decades ago and more recently by Duckworth (1987) and Fosnot (1989). Piaget (1972) argued for teachers "collaborating in new research projects" that go beyond "exercises or practical work directed toward already known results," helping them to "become researchers and to rise above the level of mere transmitters." (pp. 125-6) He

referred to the field defined by such work as "experimental pedagogy" and argued for its importance not only to the development of teachers but to the improvement of education. While I agree with Piaget on the last point, my own feeling is that for teachers it is not so crucial that the knowledge they generate be new to the world, so long as it is new to ***them*** - much like children's autonomously-developed ideas in (say) viscosity of various liquids are valuable to them even if the wider world has known them for ages.

TELLING IT LIKE (WE THINK) IT IS

This brings me back to the earlier question: is it in line with constructivism to present to teachers the constructivist framework and/or the ideas arising out of the recent conceptual-change research, and if it is, then when and how? For me, the answer to the first question is a definite "yes," for the reason mentioned earlier, that didactic presentation does not preclude construction by the receiver, although that construction is only worth the effort ***if the conditions are favorable***: if there is time to think about and react to what is presented, if the process itself of constructing is valued, and if the outcome of that construction process is valued for what it is rather than for how closely it resembles somebody else's model. Much as it is a truncated version of the variety of paths that learning takes, the Learning Cycle (Karplus et al., 1978) can serve as a useful analogy. Before the second step, Concept Introduction, must come the first, Exploration - a ***long time*** of exploration. Veteran teachers, of course, have plenty of experience upon which to base a reconceptualization, but as Duckworth (1987, p. 37) points out, it is not experience per se that matters, but what you notice in your experience and what you make of it. "What was I thinking when I thought I understood that?" "If they didn't learn what I had intended, what in fact ***did*** they learn?" Sometimes such questions and realizations can be reconstructed after the fact; often you

have to have the question in mind even as the experience unfolds.

So experiences, suitably planned and framed, can provide the fertile ground necessary for the new ideas present in an expository description of constructivism; again, provided the experiential ground has been turned over and fertilized, and that the growing season is long enough. I suppose the exposition then serves to increase the ***plausibility*** of the constructivist model, increasing its chances of being accepted eventually.

Constable & Long (1991) report on selected outcomes, one year after the fact, of a brief (two-day) inservice teacher workshop. The agenda was constructivism and teaching, as interpreted by the Children's Learning in Science project (Driver, 1989). There were many encouraging outcomes reported, in teachers' thinking if not necessarily their practice; however, admittedly assimilating their findings to my ideas, I noted that "separate opportunities for thinking" was the ***least*** emphasized of the 8 components of the workshop, both in teachers' thinking and in reports of their teaching. The workshop was brief, and intensive construction or reconstruction would necessarily have to take place ***after*** the fact. To me, the message was that time to reflect and construct is absolutely necessary, and for most teachers that time needs to be structured and planned. I suppose in the Learning Cycle that would correspond to the beginnings of the third step, Concept Application.

One way to provide more "time for thinking" is through readings. The literature on conceptual change of the last 15 years contains much thought-provoking material. Bell (1993), among many others, has put into print an exposition of constructivism and conceptual-change for teachers. An interesting feature of the book is that at frequent intervals

a section begins with a description of a situation, followed by several questions. Sometimes the questions are answered from the author's perspective soon after, but in other places they are left unanswered, or at least not answered explicitly right away. Would that one could keep readers from turning the page and immediately looking for "the answer!" Perhaps a high-tech version using interactive video with ***built-in*** requirements for interaction will accomplish that. (Apparently something like that already exists for the training of lawyers.) The low-tech version goes back at least to the *Science Teaching and the Development of Reasoning* series (Karplus et al., 1978), in which teachers are asked to articulate their reactions to selected student responses on problems and puzzles. I have had some experience using that series with teachers, and as well a set of videotapes, designed to complement the series (Konicek et al., 1983), containing unrehearsed classroom scenes followed by open-ended questions. I found that to get maximum benefit from the materials, it was necessary that a facilitator stop the turning of the page or the rolling of the tape and call for reflection and discussion.

Just as with children, "telling" teachers is no guarantee that they will assimilate what they're "told" with any kind of fidelity. If they don't, one certainly should not blame ***them***. Even experiences that we consider sure-fire bets to provoke cognitive conflict may not be seen as such. What we think of as most glaring discrepant events may be assimilated to pervasive and tenaciously-held views very different from what we might have hoped. In teacher education, I believe it is more important that teachers form their own ideas over time rather than going along with the current views. There is far less consensus about how to describe learning than about how to describe thermal conductivity, and what consensus there is is much more likely to change over time. The feedback from the environment is

much less predictable in the case of learning and teaching than with electrical circuits, and more open to varying interpretations. Teachers have a lifetime to reconstruct; it is better to provide favorable conditions for this task than to hope to prescribe the outcome in the short term.

Of one thing I'm certain. Any exposition of our "favored" point of view had better be subjected to **at least** the same level of skepticism and scrutiny as its competitors. Our culture is so steeped in the ethos of getting-ahead-by-accepting-authority that any conceptual structure introduced by the authority figure (whether lecturer or author) has a good chance of gaining superficial adherence without adequate questioning; and at the same time, ***in practice***, the official view is sure to be distorted, ignored, or subverted.

WHAT DO WE GET FROM CONSTRUCTIVISM?

Returning to Kempa's (1983) argument (see opening paragraph) about utility of theories for teacher education, constructivism provides a useful, indeed powerful, framework for interpreting teacher beliefs and behaviors and classroom interactions. As for specific prescriptions, constructivism does not provide them. It doesn't tell us what to do at any given moment; at least I don't discern a clear direction a lot of the time, and certainly not one I would want to foist upon teachers generally.

The dilemma persists: when do we support teachers' conscious and explicit reconceptualization of learning and teaching, wherever that may lead them in the short term, and when do we intervene (and how overtly) to try to assure that our viewpoint wins out? As with children's science learning, "it depends." And what it depends on seems to include a great deal of ***my*** style. Whatever the similarities between students learning science on the one hand and teachers learning about learning on the other, there are also

differences - in the nature of the learners and of what they are learning about. Whatever one may believe about the efficacy, or the necessity, of presenting science to students "as the experts know it," the balance in teacher education tips the other way: toward providing situations ripe with possibilities for conceptual change, establishing a climate of questioning, but letting teachers arrrive at and articulate their own conceptions.

Quite aside from constructivist theory, we must also recognize that school is about more than learning subject matter, and teacher education/development is about more than promoting learning of subject-matter knowledge. In the end, "telling" teachers comes down to creating conditions favorable to disequilibrium so as to increase chances of conceptual change over time. As Sigel (1978) wrote in one of the early pieces on the subject, we must help teachers "challenge and change, or at least challenge" their views. Any method that helps and motivates teachers to do this is a valid "how" in "how to tell them." To borrow a favorite line used by Sinclair (1981) about children, we should regard all teachers at all times as wearing sandwich boards with the inscription "Under Construction -- Self-Employed."

* This paper had its beginnings while I was a guest at the Centre for Science and Mathematics Education Research, University of Waikato, Hamilton, New Zealand. I thank the staff for many useful discussions. However, any errors of fact or interpretation are entirely my responsibility.

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