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ARTICLES

Gender Diversity in Play With Physics: The Problem of Premises for Participation in Activities

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The lack of women engaging themselves in science has been thoroughly discussed in feminist and nonfeminist science studies. It has remained a mystery why so few female students take professional careers as scientists. Though more and more female students enroll in physics studies, for example, they seem to disappear before they reach academic positions. Instead of discussing this as a query of gender inequality in this article, I discuss the more general issues of inclusion and exclusion in communities of practices. I argue that selection mechanisms in a group of students can be connected to their premises for engaging themselves in an activity. As students have different embodied experiences, they also have different premises for engaging themselves. What seems like the same practice can, in fact, be analyzed as practices belonging to different activities. This approach might bring us a small step further in the discussions of the relations between gender and science.

THE PIPELINE

Women in physics seem to disappear in larger and larger numbers as they get closer to tenure—what has been called "the leaking pipeline" (Schiebinger, 1999). Female students in physics do not seem to pursue careers as physicists to the same degree as their male colleagues. I assume that an analysis of the different activities the students engage in daily within university physics programs might contribute some insight to the discussions of this phenomenon.

My fieldwork with students of the Department of Physics, University of Copenhagen, aims to take a closer look into possible gender barriers in the daily life activities of an education in physics.[1] This issue raises the methodological question of how people gain access to everyday activities. I have used participatory fieldwork as a road to identify the "socially significant" (Hastrup, 1994, p. 227). My data, obtained by participating in the daily practices at the physics institute, are

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[1]The field of physics was chosen because the problem with a lack of women is an acknowledged fact in this field. This particular location was chosen because it is one of Denmark's leading physics departments.

combined with interviews and a survey of 1st-year students. At the physics institute, the male and female students apparently belong to the same community where the mastery of knowledge and skill requires newcomers to move toward full participation in the sociocultural practices (Lave & Wenger, 1991, p. 29). In this case, the practice is studying physics. The empirical material suggests diversity in the ways some male and most female students approach their studies in physics. Although all the students have equal access to physics studies, their practices differ in everyday life at the physics institute. I have found it useful to analyze these differences within the framework of cultural–historical activity theory (CHAT) dealing with actions and activity.

The analysis suggests at least two activities within the same Department of Physics. One activity centers around educating students; the other centers on making science. Surprisingly, and sometimes disruptive to the activity of educating students, there are a lot of playful actions in everyday life at the institute: with objects, with technical terms, in group play, and in toying with science-fiction-inspired questions in physics. All these playful acts can be seen as connected to the wider activity of science. I argue that what we can identify as gender diversity in practice can be seen as connected to diversity in activity.

Participation in an activity is further tentatively connected to students' former experiences. Many female students, contrary to many male students, have not had the experience of playing science fiction computer games with a group of friends, and they are not playing with physics experiments at home as an inspiration for physics studies. Although male students might also lack these experiences, almost none of the female students actively participate in play with physics, and their actions in general seem more linked to education than to play. Because play with physics can be seen as connected to science, the fact that female students rarely play this way can be discussed as one of many explanations as to why female physicists do not seem to feel at home in the field of science. What might seem to be a gender problem in a group of students all engaged in the same practice of studying physics is approached as problems of premises for participation in activities.

Gender Contrasts

The discipline of physics seems to have difficulties attracting new students these days (Ferdinande, 1995). The problem is especially acute with women, who seem to have difficulties fitting in the field of physics. The female dropout rate is higher the closer one gets to top academic positions, especially in Western industrialized countries (Barinaga, 1994, pp. 1468–1472). Many politicians, researchers, and planners have regarded this absence of women in physics as a major but not very well understood problem, not least in the Scandinavian countries (Rabo, 1997).

Denmark is no exception in this dismal picture. Female physicists seem virtually absent when it comes to academic careers in physics. A Danish study shows that there are no female applicants for half of the academic positions in the natural sciences (Staahle, 1998). Especially because women generally do well at exams, this phenomenon is considered a real mystery.[2] In 1995, the Danish Research Councils decided to make a major effort to discover reasons for the general absence in Denmark of women in academic careers. The Councils launched a project, ending in

[2] In a survey I conducted in 1996 of 68 first-year physics students, none of the female students but over 33% of the male students planned an academic career. Of the 68 students, 15 were female and 53 were male. This share, 22%, is equivalent to the share of female physics students as a whole in Denmark (Hasse, 1998a).

2001, which looked into possible social, psychological, cultural, and institutional gender barriers. My anthropological project at the Niels Bohr Institute for Physics in Copenhagen falls under this umbrella of general inquiry and looks especially into cultural impediments that might keep female physics students from pursuing academic careers. Accounting for the absence of women in academia seems to be more complicated than exposing explicitly stated gender barriers. Instead of stressing the gender barriers often mentioned in the debate (such as childcare, low expectations, menreferring other men), I have gained an experience, through the method of participatory fieldwork, of what could be described as implicit gender barriers or, as I prefer to describe it, implicit impediments within the physicist's education.[3] This approach makes it possible to see barriers as a consequence of the different activities we engage in.

Just as anthropology has cemented the exaggeration of and described "the other" as everything we in the Western culture are not (Nader, 1994), in studies of gender there is a tendency to draw a sharp division between male and female that describes men and women as oppositional; that is, everything a man is a woman is not, and vice versa. Doing gender studies implies this kind of built-in comparison and a risk of exaggeration in the writing process. Studies of gender in the natural sciences have often begun with this division line as a starting point. "Science," the feminist Evelyn Fox Keller's 5-year-old son once declared, "is for men!" Fox Keller went on to state that her son simply expressed the identification between scientific thought and masculinity so embedded in culture that children have little difficulty internalizing it (Keller, 1985, p. 77). If this applies to science in general, the notion that "physics is for men" has had an equally long and prevailing history in Western culture. Despite this general sense, the past 30 years have proven differently. Increasing numbers of women study physics; however, they generally seem to gain employment outside physics and the scientific community.[4] Physics as a scientific profession still seems to be "for men" even though physics as a discipline increasingly attracts women. The question is, Can this be connected to a gender problematic? This is where we find the core of the mystery of the gender diversity in the natural sciences.

Many researchers studying gender today would agree that gender is not about biological sex but about cultural socialization connected to biological sex. I propose to take this understanding a little further in my study. What we can analyze as culture cannot be separated from experience (Hastrup, 1995, p. 93). What can be analyzed as gender in everyday life is an experience as well as a discursive practice in the process of cultural socialization. In other words, on one hand we have daily life experiences as men and women, and on the other we learn to talk about gender in a certain way. A look at gender as connected to experience in activities could lead to a modified perspective on male and female socialization and to a more subtle way of talking and writing about gender. Within their corporal fields, people do not experience themselves mainly as gendered but primarily as living persons. By *corporal field*, I mean that larger space within which every individual is inextricably linked by way of the physical body, its sensations, and its movements (Hanks, 1990, p. 92). It is often later in "writing gender" (following the idea of "writing culture,"

[3]*Barriers* connote physical obstacles. I prefer *impediments* to imply a much more complicated, subtle relation between the individual subject and restraints in the surrounding environment.

[4]Now women comprise more than 22% of all students enrolled in physics studies in Denmark. Twenty-nine percent of the PhDs at the Niels Bohr Institute are women, but less than 5% of women have tenure. Some affirmative action has been attempted but as yet seems to have had very little effect. From 1971 to 1985, women made up 13.8% of the total production of candidates in physics. In 1996, this amount has risen to over 22% but still with no effect visible in the statistics of academic positions (Andersen, Olesen, & Nielsen, 1987; The Danish Statistic of Studies, 1996). In many cases it seems there are no female candidates for the academic positions in physics (Staahle, 1998).

as proposed by Marcus and Clifford, 1986) that gendered aspects of a lived experience in a corporal field stands out. When we write about gender we tend to operate with two groups—men and women—and in the writing process, all the variations of everyday experiences gets wiped out.

Gender Differences

When we look for gender differences we might overlook differences that are not sharply defined and cannot be distributed in two groups defined by the categories *male* and *female*. I suggest that, although it can be very difficult to analyze, we must try not to let the words seduce us and at least try to be true to our experiences. The practice of anthropology implies writing from a particular standpoint of knowing and interpreting in time (Hastrup, 1995, p. 16)—not only in experiential time, but also in analytical time. All this is to underline that I, in my fieldwork, did not constantly experience gender differences despite the fact that I have analyzed my fieldwork material from the perspective of gender. When I acknowledged this, I became aware that although my research questions aimed at sharply defined divisions, my experience in the field blurred the division lines.

One of my research questions was, Are there or are there not significant differences between male and female students? In my field notes I recorded my observations of a group of male and some female physics students. I noted that the women do not seem to participate in a kind of playful activity that I observed in the men. In the process of analysis I realized that, although my field notes mentioned playful men, I referred to the same names over and over again. Other names were never mentioned because not all the male students participated in the playful actions that caught my attention. In the end, I had to reformulate my research question to, What constitutes the differences between some male students and other male students and almost all the female students? As this question came into my research at a late stage, I can only give a few possible answers, and not very qualified answers, concerning the "invisible males," that is, those that did not engage in play. Their role in my argument is rather as a negation of the very visible playful men.

In this article I deal with three areas in which I noticed significant differences between the students, both male and female. These three areas all concern play with physics: (a) the telling of special physics jokes, (b) the use of science fiction as an ingredient in physics students' approach to science, and (c) play with physics equipment or other material objects in educational work situations or discussions. I regard jokes about physics as a kind of verbal play connected to verbal discussions, whereas play in work situations often involves a group of students playing physically with material artifacts. Science fiction is sometimes, but sometimes not, included as a verbal or visual referent in these playful actions. I have found that, from the experiential fieldwork perspective, there is a significant difference between one group of male students and almost all female students in these three areas.[5] However, there is not a significant difference between all female students and all male students. If we separate those who tell physics jokes, play with physics in work situations, and are inspired or influenced by science fiction (in my fieldwork it was often the

[5]This understanding based on my anthropological experience conflates with the survey I made among the physicist students. Here, as one example, a group of male students differs from almost all female students and the rest of the men on questions about science fiction as an inspiration to study physics. Thirty-two percent of the male students have been inspired by science fiction, whereas 68% have not. In comparison, 7% of the women have been inspired by science fiction and 93% have not (Hasse, 1998a).

same persons) from the rest, two groups appear. The first group comprises virtually only male students who joke and play with physics. The second group comprises some male students and almost all female students who do not play and joke with physics. This division makes it possible to see that the group of male students is less homogenous than the group of female students. This finding focused my analysis in a new direction. If it is not gender that acts as the differentiator between the group of male students and almost all female students and the rest of the male students, then what is it? I propose that the difference can be explained if we first look at the types of activities the students engaged in rather than begin by looking at students as gendered. Activity comes before gender in this analysis.

Fieldwork

To obtain valid data on the everyday activities of people is not easy. One way of going about it is to engage in anthropological fieldwork that looks at the physicist institution as just another culture. Working in another culture is quite a complicated process for an anthropologist. In anthropological fieldwork, the method sine qua non has been participant observation. Lately, the innocence of this method has been challenged by a number of scrutinizing questions regarding at least three problems: (a) access, (b) perspective, and (c) validation (Appadurai, 1995; cf. Clifford, 1988; Geertz, 1988; Gupta & Ferguson, 1997).

In anthropology, the question about access and the kind of access to participation is always pertinent. When that question is solved, the next issue becomes what you are actually able to see from your obtained position. The third question is how to make valid data out of participant observation. The question of access can be connected to an awareness of the position ascribed to you by the field and the position you try to obtain (Hasse, 1995). The question of perspective has been connected, among other things, to the concept of cultural background. When anthropologists work in places far from home, what presents itself to the eye is often all the differences between the culture out there and the one at home. Studying student culture at a physics institute in your own country does not seem very exotic, and yet I soon experienced that some physicist students engaged in their studies in quite unfamiliar ways.

Because anthropologists are themselves part of the class of phenomena being studied (i.e., people), there is no way of understanding people independent of our more or less shared human experience. Even the ethnographer in the field remains curiously unaware of the degree to which the experience is incarnated (Hastrup, 1995, p. 94). A reformulation of the anthropological project therefore no longer sees observation in itself as an access to a lived space. Anthropologists have to take a departure in the realities of the particular people under study. To create general anthropological knowledge, we must share their experiences (Hastrup, 1995, p. 161). This conception of anthropological fieldwork goes beyond what, in anthropological terms, has been described as participant observation. It goes beyond mere presence as a platform for direct observation. This understanding of anthropological fieldwork requires active participation or, to put it a little differently, participation in activity.

By participatory fieldwork I mean an approach that seeks to understand the phenomena under observation by studying it within its own contexts and from the perspective of everyday life, utilizing a method that tries to make the research situation as close to everyday life experience as possible. The less artificial, experimental, and observationally distanced the method, the closer you get to people's actions in the normal run of things.

By engaging myself in the activity as it is experienced in daily life, I hope to gain insight into what motivates the direction of the activity. However, even though the road to anthropological knowledge is via shared social experience, this does not imply that anthropologists simply gain access to other people's inner lives by sharing an experiential basis. The experience is always more or less shared. We are all positioned subjects. Our particular experience only allows a selected comprehension of the socially significant (Rosaldo, 1984). Anthropologists as well as all other social agents share these conditions.

This anthropological method of fieldwork brings a focus on how bodies move, interact, and place themselves in space. This also includes anthropologists' bodies. The lived body of the anthropologist becomes a path of access to internalization of culture. As positioned as this body path may be, it opens for acknowledgement of the degree to which culture is incorporated and internalized yet is simultaniously open for improvisation (Hastrup, 1995, p. 95).[6] In the figure–ground constellation, as suggested by Maurice Merleau-Ponty, our body becomes a third term always tacitly implied (Merleau-Ponty, 1962, p. 101; op cit Hastrup, 1995, p. 95). It means that bodily experiences such as being vexed or annoyed can be used as fieldwork indicators. Moreover, the world is always experienced from a particular point in space, and the point from which we experience it is in constant motion (Merleau-Ponty, 1962, p. 101; op cit Hastrup, 1995, p. 95). The validation of one's data from this kind of fieldwork lies in the argument one is able to make on the basis of shared experience (Hastrup & Hervik, 1994).

Nonmembers

To gain access to shared experience, I enrolled myself as a 1st-year student at the Niels Bohr Institute for Physics in Copenhagen and began the 1st year of study with the other students.[7] However, this does not imply that my experience mirrors everyone else's, especially because my background as an anthropologist made me an atypical 1st-year student. My fellow students might have participated in the same physics class as myself but come out with a somewhat different experience, just as my experience in fieldwork might not—or most surely does not—conflate with the experiences of everyone else with whom I have shared the experiential space. In many ways, I was limited in the task of sharing experiences with the physicists students: I am not a mathematical student, my knowledge of physics is limited, I am older than most of the students around me, and I was known to be an anthropologist. Despite this, my impression was that I was more or less accepted by the other students along the way. The more actively I participated, the more accepted I was. I followed classes, tried to do homework, tried to solve exercises with the others, and participated in many social arrangements. In this way I gained what can be described literally as "corporal knowledge" of

[6] *Incorporated*, the word used by Hastrup, and *internalized*, my addition from the Vygotskyan vocabulary, are both used here.

[7] The university administration and most of the students I encountered were aware that I am an anthropologist. I began my fieldwork in August 1996 in the introduction course by making a small speech about my project for the new students. During my fieldwork I presented my findings on several occasions at the Niels Bohr Institute. Apart from participant observation, I have also conducted interviews with elder students, teachers, and researchers, and participated in arrangements for candidates and PhD students.

the often not explicitly stated social activities in the students group. The activities we participated in were not all about education. Even though I spent most of my time in classrooms, the auditorium, or doing physics exercises, I also went to student parties, went to the Friday bar, participated in the yearly theater show, *Fysikrevy*, ate in the canteen, and visited the library and the computer room. In many of these classroom and nonclassroom settings, I experienced how annoying it can be when one is trying to solve an exercise and some male students disturb you by playing around. By their actions, this playful group of male students singled themselves out from the rest of the students, both male and female, in the classroom.

When I presented some results from my project at a focus group discussion at the Niels Bohr Institute (researchers, teachers, and PhD students of both sexes were present), some of the women expressed rather negative feelings toward further pursuing careers as physicists.[8] Even though I addressed women (and men) who had stayed in the system, the women to a certain extent still expressed a feeling of nonmembership in the physics community, and this feeling seems to be tied to problems of setting and collaboration.[9] A female scientist expressed dismay with the loneliness of the work and dissatisfaction with the leader of her group. Empathizing with her female colleagues who were expressing doubts whether the pursuit of a career in physics was worth the trouble, one of the female physicists stated, “Generally, I think a setting like this one [the physicists environment] should definitely consider what is wrong with the teaching and learning environment when the gender distribution is so saliently skewed.” Later, she continued to refer to one of the departments: “I know that the research center is pretty worried because it simply does not get any female applicants. But I must say it’s understandable when I think of some of the people working there.” Later again at the same session, another female PhD student received applause when she called for more interdisciplinary collaboration: “With more interdisciplinary collaboration, I believe most women would thrive a whole lot better.”

The irony is that the physics environment is actually characterized by an usually large degree of collaboration. Big physics experiments are almost always conducted in groups, sometimes with hundreds of scientists working together. This implies that women may be turned off from the pursuit of physics not so much by a lack of collaboration as by the way physicists collaborate. I experienced a lot of working in groups from my field research at the University of Copenhagen as a 1st-year physics student. I discovered that male students often behaved in a more playful manner than the female students when we worked in groups to solve physics exercises. They would run around stealing things from each other and jokingly comment on the inability of other groups instead of concentrating on the educational assignments.

[8]This recording is from an open meeting in the Women in Physics Club at the Niels Bohr Institute, December 1996. See also Hasse (2000) on the problem of presenting one’s analysis to the objects of the analysis, which gives new perspectives on the analysis itself in a kind of feedback loop.

[9]During my fieldwork, to my knowledge only one woman tried to get a university job but failed. In the same period the number of women employed at the institute went from 4½ female scientific employees to 3½. The number of male scientific employees is, according to the internal telephone book, 19 professors (no female professors) and 68 assistant professors.

Everyday Jokes

I observed in my field research that, although female students in many situations apparently participated in the same educational activity as male students and generally did well in exams, in some situations they singled themselves out in subtle ways by not participating in playful activities. Because I was aiming to look for gender differences, I was therefore aware of this difference between male and female students. The females in these particular situations singled themselves out by simply not participating in the playful actions, which engaged the most saliently noticeable male students. At least in the beginning of my study, in my notes I stressed the situations where I found these kinds of differences.

Through my participation in *Fysikrevy*, the local theater revue, I became part of a group of male and female students making up jokes and funny comments about their own study. In this setting, the women wrote texts for the revue just as well as the men. However, the male students had a certain way of joking in which the female students rarely participated. Whereas the female jokes often concerned gender issues and were related to problems in education, the male jokes more often referred to physics and science in general. I began to notice that this kind of joking was found among many other male groups of students I had contact with. In these jokes the male students applied what we learned the hard way in the classroom to all kinds of other, everyday situations. For example, while eating in the canteen one day, one male student reached out, touched a window, and started pushing it back and forth. We looked at him in puzzlement. Then he said with a triumphant grin, “I just found the *eigenfrequency* of the window.” Eigenfrequency in physics refer to harmonic oscillation and could also be described as cyclic frequency. In this joke, the student made us laugh because he was able to transfer his classroom knowledge of the physical concept of eigenfrequency to an object of our daily life experience. I could follow the jokes when they were rather obvious and referred to classroom knowledge that I also shared to a certain degree. On one occasion a male student started a discussion with other students about gravitation. “You can’t annul it,” he said, “Look,” and then he proceeded to make everybody laugh by jumping up and down in the elevator to test the gravitational force in terms of relativity inside an elevator moving up.

Many of these jokes I did not—and still do not—understand. They came too fast, and I was rarely able to write them down right after they were said. But the jokes that I did understand played on terms, signs, and concepts in physics by connecting them to science fiction, sex, and daily life utensils. Often the words have the ring of a secret language even for other physicist students, especially newcomers. This is not only because they refer to scientific knowledge as yet unknown to newer students; often, the jokes referred to some unknown event in the past connected with the study of physics studies and to science fiction.

The Funny Number

The students made many jokes related to science fiction and brought them into conversations in and outside of classrooms. In discussions of the new physicist theories of baby universes and wormholes, time machines were often mentioned and references made to science fiction literature such as *The Time Machine* by H. G. Wells.[10] Another example of the use of science fiction in playing with physics is the joke I observed involving the number 42. This number came to be a secret word among our group. If you knew it you were "in" and if you did not you were "out." Nothing is so annoying as having everybody laughing around you when you do not know what the joke is about. This happened to me many times in the first few months of my experience as a 1st-year physics student and sometimes involved the number 42. For example, a male senior student during the introduction course asked a newcomer how many beers he drank at the newcomer's party the night before. This newcomer proved already to know the secret language of physics studies and answered "42." Both broke into fits of laughter. I was puzzled but chalked it up to my ignorance as a newcomer to physics. Later, the number also appeared when we were solving equations in groups and someone asked, "What did you get?" A person sitting next to me answered "42!" A perfectly acceptable answer, but it was followed by a laugh. Later still, at the physicist theater show, one of the jokes was about a man who wants to send a "wave package" from a post office and draws the number 42 in the waiting line. It took a long time before it dawned on me that there was no automatic inference to be drawn from these examples. If I wanted to understand, I would have to ask what sort of former experience constituted the secret meaning of the number 42. It turned out that, to get the joke, a person had to have read the science fiction bestseller *The Hitchhikers Guide to the Galaxy* (Adams, 1995). In this fiction story, humankind obtains an enormous computer to calculate the answer to everything. After eons the answer comes out to be 42. This answer is both too much and to little, and mankind must start all over again asking the big questions.

Although most of the senior female students were aware of this connection, they did not participate in the number 42 jokes. Also, this particular meaning of 42 was unknown among the younger female students I spoke to. Very few women seemed to care for science fiction literature. When I had heard that number a few times, I asked one of my fellow female 1st-year students what it meant. Neither she nor her girlfriend knew, and she said, "I don't care. Something the boys are playing, I guess." Generally, the women seemed indifferent or even annoyed at the male students games, especially when they interfered with work.[11] My position as an anthropologist gradually changed my own perspective on the playing around from indifference or annoyance to interest. As an anthropologist I could afford to pay attention to activities other than solving the exercise at hand. Even so, I could also feel vexed by the behavior of the male students.

Annoying Play

In one of our classes, the assignment was to measure the turns of a bicycle wheel hung up on four strings. I was in a group with three other female students. Some male students attempted to steal our wheel. We had been busy trying to make it hang nice and steady when a male student came up and grasped the wheel before we were able to attach the strings; he tried to swap ours for the more crooked wheel in his group. We succeeded in pushing him aside. The male raiders all laughed. However, we were really angry because we were trying to solve the problem at hand and wanted to do it right. Ulla, one of the female students in my group, expressed annoyance because they dis-

[10]The male students expressed fascination over the possible conflations between what they knew from their science fiction readings and modern physics, and some even express this fascination in scientific articles (e.g., see Jensen, 1998).

[11]In general, the male students moved more between groups, negotiated results, and learned from each other (Hasse, 1998b).

turbed our attempt to solve the exercise and asked them to leave. We women in the group agreed that it was annoying that the "boys" were running around like that, disturbing our measurement and causing us not to get it right. The playful boys went to another group of male students, stole their wheel, and they all went around chasing each other. The other group of male students got mad as well, but they also reacted as if they had fun. They made it into a game of stealing the wheel back. Later, this game somehow developed into play that involved male students from both groups; they made the wheels spin tied to a stick, although this was not part of the exercise and took time away from doing the exercise. The now much bigger group of male students spoke about how the spin would behave if it were falling down the Eiffel Tower in Paris and played around pretending that it was. My female colleagues and I completed our exercise, but, undoubtedly, the male students had more fun. Even the teacher commented positively on the idea of letting the wheel fall from the Eiffel Tower. One of the females in my group and I stood for a while looking at the playful male students having fun with the wheels and agreed it could be fun to try. However, we did not interfere with the male students' games. Our group needed us, so we returned to them to help finish the exercise. Another group comprising both male and female students solved the exercise as planned in the textbook but did not engage in play. When they came around to do the exercise, the playful male students of course were late. Students from both the playful groups asked each other, our group, and another group for results; agreed on an estimated measure; and finished almost on time.

Some teachers seemed to mind these disturbances, whereas others did not. Another time I was in a group with one male and one female student. As is so often the case in mixed groups, the male student was in front of the computer keyboard, and we, the two female students, were looking over his shoulders. The exercise told us to make some kind of net structure in a program language called IDL. Instead of solving the exercise, the male student started to play with programming to see if he could make a ball instead of a net. The female student and I started to worry whether we had time to solve the exercise. But the male student received encouragement by the teacher because the teacher found the new problematic the student had invented really interesting (Hasse, 2001).

Good and Quiet Students

In my conversations with male students or when listening to them talk, they often spoke about life in space and would mimic a certain teacher connected to NASA's Mars Pathfinder project. The students would often talk about the possibilities for finding life in space and made jokes pretending they were this teacher actually finding "little green men" on Mars. This very popular teacher also played with physics in unexpected and spontaneous ways, like throwing a piece of chalk across the room to demonstrate a point. In contrast, none of the female physics students I was with seemed particularly interested in imagining life in space, and I did not hear the women engage in the same kind of play or discussions of play with physics as the male students when we were eating, selling tickets for the theater show, or walking down the street. We talked about teachers, homework, cinema, boyfriends, and other things outside the institutional life. It seemed the women were not interested in playing with physics, even in an institutionalized form. At the Niels Bohr Institute they have something called The Playground where students could go after hours and literally play with physics. I knew a few women from other years who went there, but no women from my own group of 1st-year students went.[12]

It is worth noting that the same male students who played around also participated in educational activities and generally did their homework. This was also the case in male–female groups that did not play around. However, I discovered that some male and most female students tended to participate and collaborate in different ways, especially when play is involved. One of the most salient differences was how some men brought play into physics studies and used play to build up a certain kind of collaboration.

Female students rarely participated in this kind of playful activity. When I say rarely, I do not mean that they never laughed at jokes. A few times I heard women initiate jokes, but they never initiated group play. During my entire fieldwork, I met some women who had read science fiction and played computer games, but very few. This corresponds with the survey I made among 1st-year students in 1996 in which 7% of the women and 32% of the men explained that science fiction had inspired them to study physics (Hasse, 1998a). The women I worked with were indifferent to playful activities and often considered them a nuisance when they interfered with solving exercises. Female students seemed to build relations with teachers just as well as male students. Teachers generally describe them as good students in interviews. However, in daily life teachers rarely praised the female students for their studious good behavior, whereas the male students who played around received praise from some of the teachers for their innovative experiments. Other teachers asked them to be quiet and not disturb the classes. In a "feedback-loop" session, where I got feedback on my analysis by presenting it to a group of lecturers in science, one of the external examiners connected with the Niels Bohr Institute said, "I get so happy when I see what they do in physics exercise class. Half of them are playing around and we reward that. The playful students get rewarded for being creative and showing initiative!"[13]

Thus, my field research reveals that, somehow, only some male students and some teachers seem to share the desire to play (or praise play) with physics. Other male students do not actively participate. The female students were either onlookers or annoyed by or indifferent to the playing around, but they did not initiate playful activities. By going through my notes I realized that it was impossible to speak of a group of female students standing in opposition to a group of male students. Many men were just never mentioned. These students were generally quiet, and not as noticeable to me as the playful men and the laborious women. I really cannot say much about the men who were never mentioned. The reason I noticed the group of women at all was due to my primary research question concerning gender. Because I was looking for differences between men and women, for a long time I saw only a gender division, whereas my notes actually mirror a division between playful and not-so-playful students.

Play

A few differences seem to appear between the group of not-playful male students and the group of female students. Although they share with the female students an abstinence from active play with

[12] In the survey, 13% of the men listed this as an important activity for the study of physics, but none of the women listed it as important (Hasse, 1998a).

[13] Presentation and discussion with male and female scientists on February 6, 2002. For further clarification of the feedback-loop method, in which analysis is presented back to the people a researcher works with as a participant observer, see Hasse (2000).

physics, the more quiet men never expressed any annoyance with the playful men in my presence.[14] In contrast, the female students I worked with expressed annoyance when the play threatened the educational activity. By putting the educational activity, doing homework, and solving exercises first, the female students behaved as perfect students. In verbal conversations many teachers expressed content with the group of female students for being very studious and “doing their work right.” Yet teachers in daily interactions sometimes seemed to be annoyed at the women when they asked questions about how to solve the exercises. The teachers often seemed to prefer the more innovative playful male students by praising their innovations, even if they had strayed from the task of the textbook. As a woman, I often felt this as an injustice and I could not understand why play should be rewarded until I engaged in a deeper analysis of my material.

There is an extensive literature on the defining qualities of play. Here I use Vygotsky’s ideas on the role of play in development. Pleasure is not a defining characteristic of play in itself, according to Vygotsky. Instead he proposed hidden rules and imaginary situations as characteristics of all play. In an imaginary situation, it is the subordination to rules that gives maximum pleasure. Thus, the essential attribute of play is a rule that has become a desire (Vygotsky, 1978, p. 99). Although his argument applies to discussions on child development, I find it useful for my discussion of male students’ play as well.

According to Vygotsky, play is the fulfillment of needs, and needs are defined in the broadest sense to include everything that is a motive for action (Vygotsky, 1978, p. 92). When a need cannot be immediately fulfilled, the need is literally played out. An unrealizable desire is fulfilled in imagination. Therefore, elements of imaginary situations will always be part of play, just as there is no such thing as play without rules. The imaginary situation of any form of play already contains rules of behavior, although it may not be a game with formulated rules laid down in advance (Vygotsky, 1978, p. 94). Vygotsky gave the example of two sisters playing at being sisters. In this game, what goes without thinking in daily life is put on display as sisterhood—each sister tries to be what she thinks a sister should be. The play of sisters induces the two girls to acquire rules of behavior; only actions that fit these rules are acceptable to the play situation. The role the child fulfills and her relation to the object (if the object has changed its meaning) will always stem from the rules. In the development of play itself, the predominance of the imaginary situation changes to the predominance of rules. Vygotsky ended by stating that play is not the predominant feature of childhood but, rather, a leading factor in development.

Vygotsky’s argument is much more elaborate in dealing with the inversion of the object–meaning ratio and the action–meaning ratio, but I do not go further into this at this time. So how does a child, in Vygotsky’s words, float from one object to another, from one action to another? Vygotsky (1978) proposed that this is accomplished by movements in the field of meaning that subordinates all real objects and actions to themselves. Following Engeström and Leontiev, I propose to discuss whether this can be elaborated on by looking at play as actions within an activity system, where the essential attribute of play is inseparable from the object of the activity.

Activity

A number of useful tools of analysis can be found in cultural–historical activity theory. Engeström (1990) listed three methodological principles of analysis: (a) the entire activity system as a unit of

[14]See Hasse (1998b).

analysis, (b) historicity as the basis of classification, and (c) inner contradictions as the source of change and development (pp. 77–84). I confine myself here to the activity system, or rather the activity systems, as the unit of analysis.

The six components modeling the basic structure of human activity, as identified by Engeström, are subject, tool, object-outcome, rules, community, and division of labor (Engeström, 1987, p. 78).[15] In the model proposed by Engeström, the subject refers to the individual or subgroup whose agency is chosen as the point of view in the analysis. The community share the same general object. The object refers to the raw material or problem space at which the activity is directed and which is molded or transformed into outcomes. The tools are the mediating material tools as well as signs and symbols (Engeström, 1990, p. 79). Following Vygotsky, the tools can be understood both as technical tools and as psychological tools, because both mediate activity. However, according to Engeström, only psychological tools imply and require reflective mediation and consciousness of one's own (or the others person's) procedures (Engeström, 1987, p. 60). The community comprises multiple individuals and subgroups, or both, that share the same general object. The division of labor refers to both the horizontal division of task between the members of the community and to the vertical division of power and status.

Finally, the rules refer to the explicit and implicit regulations, norms, and conventions that constrain actions and interactions within the activity system (Engeström 1990, p. 79; see Figure 1). Making the whole activity system the unit of analysis is a focus on each of the six components (the individual subjects, their shared general object, their tools, their rules, the community as such, and its internal division of labor) of the system, relations between them, and the inner contradictions in the activity system. The activity system is further characterized by a hierarchical structure, as proposed by Engeström (1987). Each of the six components can be seen as a three-layered hierarchy that follows the hierarchical structure of activity proposed by Leontiev, which connects operation to conditions at the bottom level, action to goal at the middle level, and activity to motive at the top level (Engeström, 1987, p. 154; Leontiev, 1978). In this figure, the motivation leading to an outcome lies in the object. Indeed, the object seems to guide not only the tools the subject uses but also the rules she lives by, the community she relates herself to, and the division of labor positioning her in that community. An object is both "anything presented to the mind or senses" and "an end or an aim" (Webster's Dictionary, 1987, p. 257; op cit. Engeström, 1990, p. 181). In other words, the object is both something given and something anticipated, projected, transformed, and achieved. Cultural–historical activity theory is rooted in the notion of the object-relatedness of human activity. No activity is objectless. Therefore, scientific investigations of activity necessarily requires identification of the object. The object is thought to be comprised in the hierarchical structure of activity and can be difficult to find from looking at actions alone.

To look only for problem or task actions that are found in the middle of the model tells nothing of the wider activity. It is only when an action can be seen as created in joint activity with other people that the determined direction of the activity—the object—can be somewhat encircled. This implies a focus on the activity system as a whole. The example given by Leontiev is about a hunt in which a beater frightens the game away. Although the beaters' immediate need tells him to get the animal, the activity makes him frighten the deer to run away. This is caused by an activity that

[15]The top part of Engeström's model is actually labeled *instrument*. However, for the argument I make here, *tool* seems a more appropriate word. Engeström further built in production, exchange, and distribution in the three inherent triangles—concepts I do not elaborate on here.

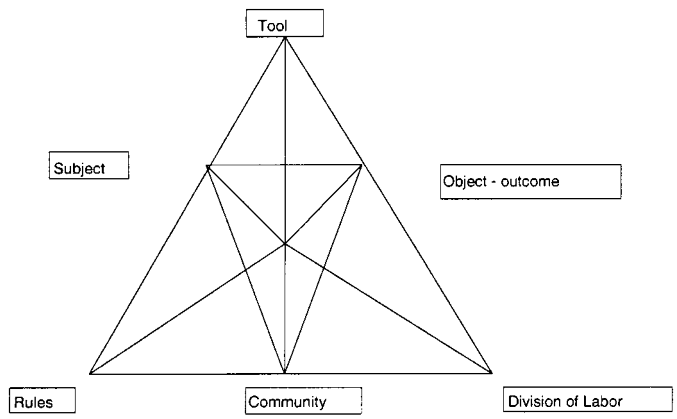

FIGURE 1 Y. Engeström's original model of an activity system reprinted from *Learning by Expanding: An Activity-theoretical Approach to Developmental Research* (Engeström, 1987, p. 78).

is governed by connections and relations that are social. Although the beater at the action level goes against his own immediate needs, his desire is fulfilled in activity that is determined and directed as a joint activity (Leontiev, 1981, p. 212).

It is exactly the object of an activity that gives it a determined direction. In this analysis, the activity becomes the frame defining the actions. The activity system in other words becomes the context for actions; the true motive of activity is its object (Engeström, 1990, p. 78). The object can be either material or ideal, and either present in perception or exist only in the imagination or thought. The concept of activity is necessarily connected with the concept of motive. Activity does not exist without a motive (Leontiev, 1978, p. 62). Activity systems are never static but are always on the move. It has been proposed by Engeström that these developments are inherent within the systems themselves as contradictions, leading to double binds and finally to development (Engeström, 1987). This connects to the Vygotskian theory of play in so far as play in itself seems to solve a contradiction between an immediate need and the problems of fulfilling it. In play the child not only fulfills the need but also develops by learning the rules of the activities that lie ahead. Through the imagination, people can prepare themselves for reality. Play in this sense becomes a kind of preparation for something else.

Encircling of the object of the activity is an analytical attempt to identify the outcome of the activity, as proposed by Engeström. In other words, we must try to identify the often implicit and hidden deeper motives for actions. In activity, actions might be diverse or similar to each other; what holds the activity together is the relations and connections between the actions people engage in. Activity seems to imply division of labor, which again implies some degree of collaboration.

DISCUSSION

The activity system of a physics education could be described as shown in Figure 2. The activities of going to class, accepting the teachers' role as educator, and accepting your own role as a student, with the

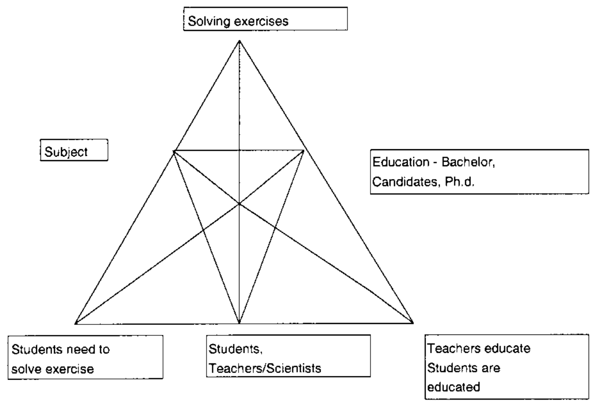

FIGURE 2 In this version of Engeström's original model, the subject in an activity system where *education* is the object must use the tool, *solving exercise*, to reach the outcome, *getting a degree*, because in this activity system the community of teachers and students follow the rule, *students need to solve exercises*.

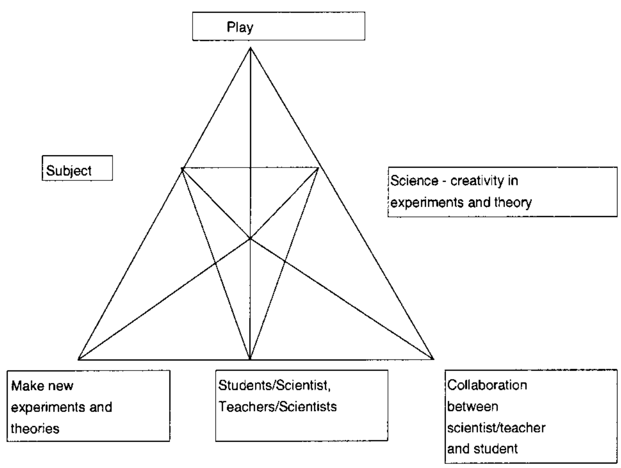

FIGURE 3 In this version of Engeström's model, the subject in an activity system where *science* is the object must use the tool, *play* (with educational tools and science fiction), to reach the outcome, *creativity in experiments and theory*, because in this activity system the community of scientist–teachers and students-as-scientists-to-be follow the rule, *make new experiments and theories*. Because play and science fiction can be seen as tools to reach the outcome (i.e., more creative science), play with educational tools and science fiction discussions are praised.

aim of solving exercises proposed in textbooks, all seem directed by the object of education leading to the production of candidates, PhDs and bachelor's. Both the teacher and students are differently positioned subjects in the activity system in terms of division of labor (i.e., the teacher educates, the student learns), but they share the object of education. Solving exercises is one of the tools to get an education. Although the aim of the educational system also might be to promote creativity, when students act in a creative way their behavior might interfere with the educational activity.

Even though both male and female students participate in education, some male students also engage in play; in these situations, a contradiction appears. By playing with the exercises given in the educational activity, the student disrupts the performance of the exercises for himself and for others. The playful students no longer collaborate with the teachers in the production of education. They seem to engage themselves in a new kind of activity, following other rules rather than the rules of solving the exercises. In this other activity, play becomes a psychological tool directed at what could be seen as a preparation to be creative scientists. In this play system, education is simply a means to do science and answering the big questions of the universe (see Figure 3).

Because some teachers support the playful activity of the male students, who also solve exercises, the contradiction is to be found between the students trying to solve exercises and the teachers supporting the playful activity and the playful students. As already noted, many male students were inspired to study physics through their previous experiences with science fiction themes. From another angle, science fiction literature often deals with the big science questions such as "Is there life in space?" or "Is time travel possible?" Famous physicists like Steven Hawking, Carl Sagan, Michio Kaku, and Lawrence M. Krauss have not only dealt with these questions but also even connected them directly to questions brought up by science fiction (Hawking, 1995; Kaku, 1994; Krauss, 1995; Sagan, 1979, p. 162).

Another point to note here is the experience some young men bring with them of playing in large groups. The results of a 1998 telephone survey of a group of 46 students, which included 10 women, revealed that many male students, unlike the female students, have had experiences with group play in larger groups.[16] Physicists tend to believe that the way to do science is to work in groups. They often work in very large groups and often in open competition with other large groups working on the same big questions. An example of this is the physicists' research center, CERN, in Switzerland, where as many as 1,000 physicists work together in competition with other groups of scientists to solve the same kind of questions. Finally, playing with objects seems to be part of a physicist's creative work. In a questionnaire sent out to the freshman students in 1996, about one fifth of the male students and only one woman had played with making up their own experiments with physical objects (Hasse, 1998a, p. 20).

Thus, by making small playful experiments in canteens and elevators, playing with new ways of posing problems, playing in groups, and having an interest in the questions posed in science fiction of life in space and time machines, some of the male students seem to prepare themselves for some of the rules found in "grown-up" physics. These rules include making new experiments, playing with creative theories, and collaborating in large groups for the development of new ideas.

Education is in itself a preparation for a career in science, but the institution is not telling the students directly about all the skills they will need to become scientists. As the external examiner noted

[16]My assistant, Birgit Oksbjerg, conducted the interviews in the summer of 1998. Apart from interviewing 37 students from my freshman group, we included 9 tutors in this mini-survey, which took place between February 6 and April 28, 1998.

at the feedback-loop session mentioned earlier, the playful get praised more often than less playful students at exams because through play they show initiative, only this message is never explicitly stated as the institutional agenda. It is no wonder that many male and female students believe all they have to do is to solve the exercises as correctly as possibly. They were never told to look out for the hidden messages in the physics culture at the institute, and thus they do not learn that play is an asset in this particular environment. So why do most teachers consider play an asset? Play might be part of the preparation for a scientific career because through play the male students learn some of the hidden rules of science on how to be innovative, how to collaborate in groups, and how to make new experiments. Many male students bring embodied experiences of playing and collaborating in large groups with them into the institute, and they are rewarded for doing so. Some male students and almost all the female students lack these embodied experiences. What makes a difference in the group of students is not gender but experiences with experiments with objects, group play, and science fiction. From this position we researchers could go on to note whether such experiences really are gendered. In time we might also discover more about whether these premises are actually important for entering the activity of physics research. Unfortunately, the available data are not sufficient to make any conclusive statements about these points.

I want to point out here that, analyzed as an activity system, there seems to be hidden a contradiction expressed as a conflict between teachers and male and female students within the institutional setting. Some students and teachers seem to support each other in the system of education, whereas other students and teachers seem to support the science-preparation system. Teachers and students view the playful acts differently. This points to the relational aspects of acknowledging other people's creativity (Hasse, 2001). From the point of view of the individual learner, the teacher does not always provide support for the student's progression, as noted in a somewhat different context by Peg Griffin and Michael Cole (1984, p. 62).

I suggest that we at the Niels Bohr Institute find students and teachers motivated by two related objects—namely, education and science. In real life there is no sharp divide between the two, but, rather, they interact. In addition, there are many ways to do science, not only by playing. The point here is that many female students do not engage themselves in play and thereby exclude themselves from what might be an important part of the process of preparing to be scientists. The object of education is where the goals are to solve exercises and where the student and teacher collaborate to produce education in the division of labor. This object is shared by students who do not play around and by teachers who talk about passing exams. We also find another object shared by some students and teachers. This object is a playful science-preparation that aims at becoming a scientist. Even though the male students are still in the activity of getting an education, whenever they play, in the Vygotskian definition of play, they seem to get a little closer to the rules of science. In play, male students often transform the purpose and goal of the textbook exercise by making up their own experiments. In doing this, they encourage themselves to master one of the rules of science, which is to create new experiments. In horsing around between groups, they learn another hidden rule of physicist science—the comparison between groups (Hasse, 1998b). In play inspired by science fiction, students can be seen as preparing for dealing with some of the big questions that occupy scientists, such as life in space. This transformation of the object also transforms the goal. When the activity of science replaces that of education, education is reduced to a goal, not the object of the activity in itself. Attention to classroom teaching and taking exams are no longer important in themselves but can be seen as a tool to achieve the object with the outcome of becoming a scientist.

CONCLUSION

Vygotsky argued that there is no play without rules. Leontiev argued that there is no activity without a motive. Engeström argued that there is no activity without rules and an object. If play can be considered a psychological tool to learn how to be creative in science, it seems to me that the play of male students in many situations follow the rules of science. Games like creating new experiments on windows, bicycle wheels, and elevators prepare them for lives as scientists, and their games show a need to play out their imagination. The motive for these activities can be seen as a desire induced by play to become scientists. In the hierarchical structure of activity introduced by Leontiev this might be the motive on the level of activity that links teacher–scientists to student-scientists-to-be. What holds the activity of science together are the relations and connections between the actions people engage in. At the action or goal level we have seen a contradiction between the actions of the playful males and the studious female students. This is not the collaboration of separate actions within the same activity system as in Leontiev's hunting example. Female students do not seem much interested in the playful actions of the male students. From their point of view, play interrupts with what they see as the motive behind the educational activities—to learn solving exercises and pass exams without annoying interruptions. Hence, the playful actions are not considered by the laborious women as part of the same activity they engage in.

I propose this dilemma can be discussed as being not one activity system of education, but rather two: one of education and one of play as science preparation. Both are necessary for the activity of science. Because many female students do not participate actively in play with physics, the desire to engage in science is more likely linked to education than to play and thereby to another level of preparation for engaging in science.

The fact that most female students do not play with physics and sometimes are annoyed by the male students' play in itself cannot explain why female physicists have problems with the physicist environment and find collaboration difficult. At most, this situation can be only part of the explanation. Time-consuming childcare and other often-mentioned gender barriers such as male preferences for male colleagues are in no way ruled out as impediments to women's careers in science. Still, the playful activities connected to science might point to play as a kind of implicit impediment within a physics education for some students who lack the implicitly requested premises for being recognized as a scientist-to-be. In this instance it seems as if the lack of certain experiences that apparently are not connected with the official educational ideological discourse might work as impediments for participating in activities.

Can we speak of gender diversity in play in physics? Here, activity seems a more useful starting point for analysis than gender. If we follow an analysis built around the division between a group of male students and a group of female students, we find gender diversity between male and female. However, in daily life experiences this division line becomes blurred when we find people, male and female, engaged in different or similar activities. The gender diversity in this analysis appears in the heterogeneity of the group of male students compared to the homogeneity of the group of female students when it comes to playful acts. Male students, to a larger degree than female students, seem to engage in more activities (both education and play as preparation for careers in science) at the institute than the female students, which gives the male students as a group an advantage. This advantage can be discussed as connected to former activities acting as premises for participation in new activities. This is why teachers often describe the female students as good students, but some of the male students engaging in playful activities are praised as excellent.

The differences in attitudes toward play and praise of playfulness is not only about differences between male and female students. The connection between the scientist–teachers and the scientist–students is the activity of play with physics. Some students have embodied premises for getting praised for acts which seem meaningless to other students and some teachers too. The playful students as a whole gets praised for being innovative and on the road to become future scientists. Some students, male and female, do not make a strong showing as they work hard in a quiet way. They are not praised for being creative, although they might be creative in ways that are less recognizable. It might come as a surprise to these students that play is praised as an important activity because it is never stated explicitly in any official university documents that play can be important for becoming recognized as an estimable physics student. For the laborious students it might be a source of frustration that other students get praise for disrupting class with their play; small everyday frustrations like these might eventually lead to a decision to leave an environment in which the rules for praise cannot be understood. Failure to engage in this playful activity might result in shutting out not only female students but also male students engaged mainly in the educational activity system from preparing themselves in important ways for doing science, and in the end this may be part of the reason they chose to leave science all together.

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