

## **The Role of Science in General Education: The need to cross boundaries**

A central position we share with Atkin & Black (2003) is the educational exchange with respect to a broader context of learning as a matter of identity formation. They argue that traditional patterns of schooling as reproduction through cultural transmission do not adequately reflect science in the real world and thus by implication do not provide a basis for seeing how science fits into its social contexts; And furthermore how students can see how science is involved in the larger society in which they come to define themselves. Atkin and Black conclude (p. 79) "that the school should mirror the world of science itself, which is one of separate communities of practice, yes, but also one in which communities interact and borrow across their boundaries, move the fences whenever it seems convenient and create new enclaves for new communities."

Boundaries in a system define zones between competing communities and an environment. According to Krohn & Küppers (1990) these communities are self-organising systemic entities protecting their identity and boundaries through pictures of self, patterns of communication, rules, norms, values or routines. The openness of these zones as well as the innovative potential of the outer boundary zone between communities are important aspects for change.

For educational reform it is a challenge "to find some new ways of enabling curriculum makers and teachers to find new ground in selecting what should be taught in the school, the enacted curriculum". In some of the studied countries "such reforms involve departing from traditional ways of sequencing and teaching science subjects; for example: teaching an unfamiliar content in science courses; achieving new kinds of outcomes for science education; engaging students more in science and its role in society" (Olson & Lang, ISATT 2007). It is a dynamic process of constantly evolving purposes that requires collaboration of different communities across boundaries, where teachers can provide insight into reform initiatives.

This kind of boundary crossing can be described as a process of shared meaning making among communities of practice (Wenger, 1998; Tuomi-Gröhn & Engeström 2003). In curriculum innovation it signifies new paths for teaching and learning beyond traditional boundaries of subjects, classrooms, school systems and cultures. It is a broad and little studied category of cognitive processes emphasizing the potential of innovation and creative thinking.

This collaborative process can take different appearances such as an open forum for face-to-face interaction, a setting such as a learning studio (Lambert, 2003) or a shared virtual space for Computer Supported Collaborative Learning (CSCL, Paavola, S. & Hakkarainen, K. 2005). If we accept that enhancing the potential of science education in the curriculum depends on a greater interaction amongst the sciences, how can this potential be achieved? More exactly what role can teachers play in this? How can teachers work together to cross boundaries? This is the theme of this paper.

## **Teacher Capacities for Boundary Crossing**

A main concern of European and other countries, seeking to improve quality of schooling is the insight of an OECD study (2005) that "teachers matter" as professionals in reform requirements. Unfortunately teachers professional status and voice that could matter in educational policy are not sufficiently considered (Olson, 2002) or in need of better professional support. Gräsel et al. (2006) note in an overview of different studies that the traditional pattern of teacher education of short interventions needs to be replaced by a long ranging strategy for teacher professional development as situated, school-based activity in cooperating communities. This cooperation especially offers the chance to develop perspectives beyond common patterns to teach separate courses such as physics, chemistry, biology or mathematics without practical relevance. Gräsel et al. therefore suggest different flexible forms of cooperation with trans-disciplinary context approaches; Atkin & Black (2003) or Olson et al. (1999) favor a comprehensive curriculum for shifting of boundaries such as STS (Science, Technology, Society) or integrated science.

The importance of joint work in educational reform will be that teachers exchange their experiences in a discourse and develop a shared vision of working and learning together bringing more coherence in the overall curriculum and finding common ground in selecting what should be taught in the school. It is a complex task with various demands in a social environment. Various players have to be convinced, issues to be negotiated, rules and agreements to be considered. Such a process is reflected in the design of the Curriculum Workshop to which we now turn.

The Curriculum Workshop originates from Schwab's (1978) suggestion of a deliberative team and Frey's (1983) model of Curriculum Conference for school-based curriculum planning and justification. It was elaborated for case studies in a European project about innovative teacher education (Lang et al. 2007). In these case studies teachers developed a variety of modifications and creative alternatives for innovative planning in their schools. This was leading to the insight that the curriculum process and aspects of innovation were not sufficiently defined and should be elaborated more precisely. This was leading to a further step to describe the innovative aspect and the Curriculum Workshop process as boundary crossing of different communities of practice in a consecutive project.

## **Discourse About Curriculum as a Strategy for Innovation through Curriculum Workshops**

In a Curriculum Workshop teachers, teacher educators, educational researchers and experts are invited to develop a shared understanding in a discourse about a common key question for change of educational practice. Basic elements for the support of this discourse are a source book about this key question, discursive rules and an agreement on a schedule and a curricular output (see figure 1). Workshop participants are arranged in a central circle for discourse and an outer circle of invited experts on request.

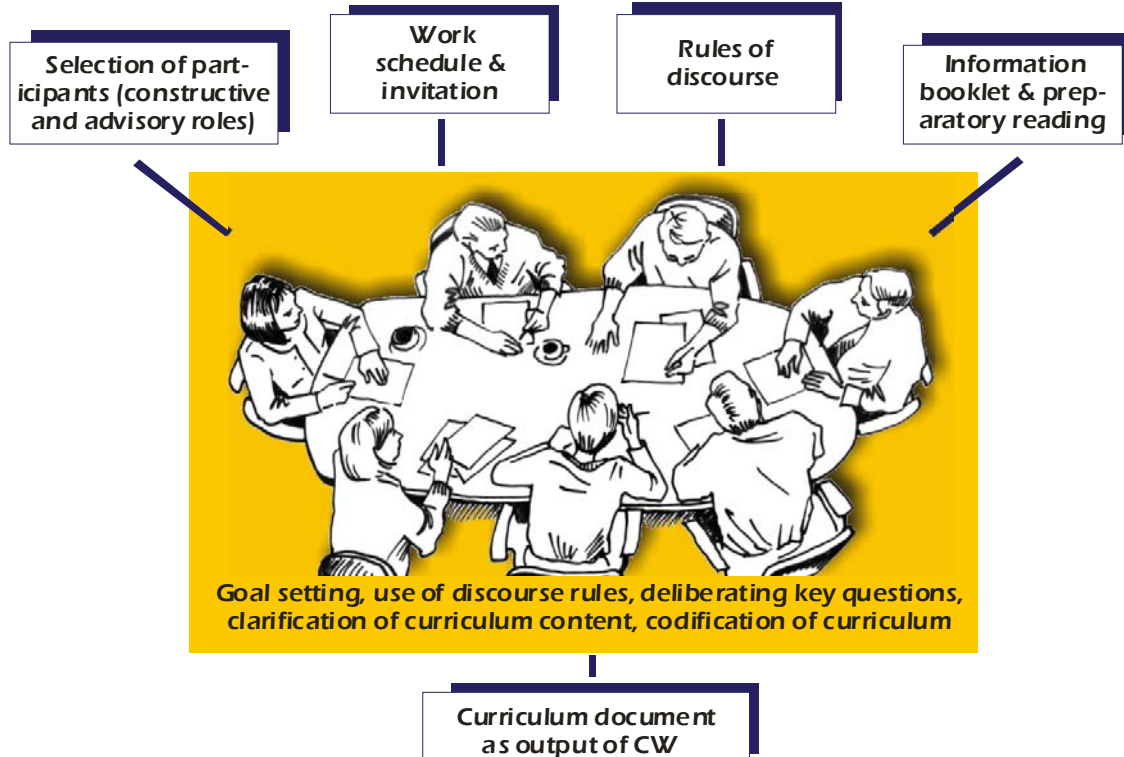


Figure 1: Elements of a Curriculum Workshop

In a project with five European partners national case studies were conducted about the process and results of this workshop approach. National partners nominated four innovative schools willing to participate in the project. Two teachers from each of these schools collaborated with teacher educators and educational researchers in a national group of about 10 to 12 persons. The national case studies were conducted between 2002 and 2004 following the consecutive steps of initial case studies, conduct of national Curriculum Workshops and monitoring of feedback and impact of the curriculum design.

Teachers found that the structure of the Workshop supported the process of collaborative curriculum development. The selection of participants, the development of key questions, the elaboration of the curriculum documents and the discourse of participants were managed in a positive way. The development and use of the source book about the key question was insufficient and judged less positively, especially the range of content, the use to prepare the discourse and the use during the discourse. The arrangement of a central circle with teachers, teacher educators and other stakeholders with an outer circle of science and didactic experts was not useful for a discourse, because these experts were not accepted or the experts dominated the dialogues.

The basic idea of a collaborative discourse across boundaries with teachers and other participants in the Curriculum Workshop is an ideal that was realized within limits.

Raising teachers voices was an intention of high priority but especially in conflict with roles and intentions of other players in the discourses during the Curriculum Workshops. Teachers rated expert knowledge generally very high accepting in some cases a subordinate role of passive consumers or completely rejecting experts instead of dealing with them as equal partners for collaboration. Teachers of one country and a national coordinator as small collaborative groups were in all cases actively involved in the process of finding a key question about their problem of innovative needs and collecting information for an information booklet. As a small group of closely related communities from different schools they were able to exchange across boundaries of schools, levels and science subjects. Feedback to their schools and school administration had varying effects depending on teachers' collaborative skills and background.

### **Aspects of Boundary Crossing in Curriculum Workshops**

For further analysis of the collaborative process in Curriculum Workshops based on themes across subjects and transitions in schools the concept of "boundary crossing" was used.

In an educational system boundaries are manifold: In science education they are raised and defined especially as boundaries of disciplinary knowledge and methods of inquiry for different school types and levels (Granville & Reilly, 2003). They are stabilized as system boundaries by political decisions about school structures and curricular units, administrative units of universities, school departments or teacher associations and regulations for grades, certificates, teacher accreditation or students' expectations.

In the research literature crossing boundaries in education is mainly viewed as a social or cultural concept. The sciences and science subjects in schools are seen as cultural artifacts of human endeavor and not as closed systems of universal academic knowledge and methodology. As noted by Aronowitz & Giroux (1991, p. 140) the historical basis of the disciplines has been largely overturned: "There are new, socially constructed objects of knowledge, and new ways of seeing them, that radically transgress disciplinary boundaries. But the paradigm of social and cultural knowledge also challenges the Enlightenment conception that knowledge be constructed on irrefutable foundations that are the irreducible starting point of inquiry."

Referring to the situation in schools Aikenhead (1996, p. 1) "offers an account of students' lived experiences in a science classroom by considering those experiences in terms of students crossing cultural borders, from the subcultures of their peers and family into subcultures of science and school science". In this sense science itself is a subculture of scientists; Science subjects in school are a subculture of science educators that both share a system of meaning and symbols with which they interact socially. The features of a science subculture are viewed as mainly mechanistic, materialistic, masculine, reductionistic, mathematically idealized, pragmatic, empirical, impersonal, universal, decontextualized, value-free. As a consequence the taught science curriculum provides students with a parallel image of socially sterile, authoritarian, non-humanistic, positivistic objects claiming absolute truth, acceptable for a small group of students with

professional career aspirations in science and congruent subcultures of their families and peers. It does not offer students a broad perspective such as the Science Technology Society (STS) approach or the literacy they need as citizens (Olson & Lang, 2004). A general prerequisite of boundary crossing is the teachers' or teacher educators' role as translator, tour guide or cultural broker in a learning community. As proposed by Aikenhead (1996, p.18): "The tour guide teacher makes the subculture of science accessible to the "tourist" students by methods predicated on cross- cultural instruction".

Star & Griesemer (1989) view the scientific work as a social activity conducted by diverse groups of actors like researchers from different disciplines, amateurs and professionals. A central requirement is to create common understanding and to ensure reliability across domains. This is not a matter of formal reproducibility of results as defined in scientific epistemology but of translation, negotiation, and simplification among social words. Reproducibility is an assumption only relevant for scientists, because their definitions and theories are based on generalization excluding diversity of empirical findings. Star & Griesemer argue from a sociological point of view that in science no less than in other kind of work diversity is not a problem for the success of scientific work but only of translation to cross boundaries in communication.

Crossing boundaries of classrooms, of cultures, of home or school learning through a physical and intellectual journey allows new experiences and a voice of students and teachers offering their experiences in a wider discourse (Aronowitz & Giroux, 1991). It is a new approach for curriculum development challenging innovation in teacher professional development, student learning and school development in a collaborative discourse. This discourse is a chance for students and teachers to find a voice in a public forum for research across classroom boundaries and educational policy of a Curriculum Workshop.

But how can teachers learn to cross boundaries in school or practice their new role as tour guides? Main attempts are collaboration between communities of teachers, researchers and teacher educators in schools.

The structure of collaborative settings may be guided by activity theory looking at artifacts and people embedded in dynamic activity systems as proposed by Engeström (2001): A teacher is the *subject* of her design work, the initial *object* would be an idea, order or assignment that triggers the design process. The initial object is necessarily ambiguous, requiring interpretation and conceptualization. Thus, the object is step-by-step invested with personal sense and cultural meaning. The object goes through multiple transformations until it stabilizes as a finished *outcome*, for example a prototype or a curriculum product. This process is only possible by means of *mediating artifacts*, both material tools and signs. The work in a team calls attention to the designer as a member of a *community*. Within the community, the members continuously negotiate their *division of labor*, including the distribution of rewards. The temporal rhythms of work, the uses of resources, and the codes of conduct are also continuously constructed and contested in the form of explicit and implicit *rules*.

In a complex system several communities are involved e.g. teacher design teams, politicians, parents or customers. Opening up and making visible the activity systems of

key stakeholders or users is the logical second step of expansion. This requires that the unit of analysis is extended to include minimally two interconnected activity systems such as the following from two communities of teachers and others (figure 2):

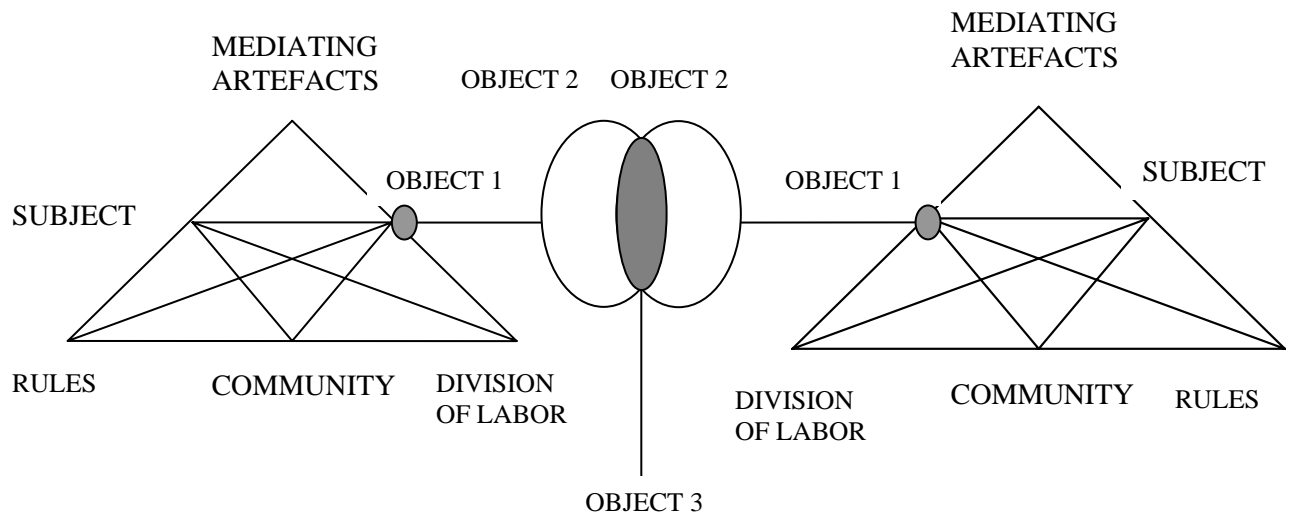


Figure 2: Two interacting activity systems as minimal unit of analysis for expansive design (Engeström, 2001, p. 131)

How can this model in figure 2 be used for structuring the process of a setting for collaborative curriculum planning such as the Curriculum Workshop? A main aspect is the representation of participants as subjects of different communities of practice with the task to develop with mediating artifacts a shared meaning about a curriculum output as object of innovative planning. Mediating artifacts are tools for boundary crossing supporting the process of sharing meaning through boundary objects. Mediating artifacts are physical representations such as materials for teaching and learning or mental objects such as signs or language. Boundary objects can be curricular concepts, educational materials, key questions or information booklets. Teachers, teacher educators and researchers are subjects of communities with different roles about division of labor. They should be representatives or stakeholders of their communities. In a Curriculum Workshop structure these subjects of different communities agree on rules such as the discursive rules for communication or a schedule.

The problematic status as experts in the outer circle of the Curriculum Workshop can be viewed as representatives of multiple communities for horizontal boundary crossing (Engeström, 1995) without special external status in the Curriculum Workshop.

Objects about curriculum innovation are defined as products of boundary crossing between participating subjects of different communities. In some cases participants will successfully cross boundaries and get to some agreement about curriculum innovation in other cases boundaries will be kept or opened for an intermediate step or "springboard" for agreement on fundamental questions to contrast divergent views ( Engeström, 1995).

The following table 3 summarizes comparable elements of the Curriculum Workshop and activity theory and new perspectives of a Curriculum Workshop for boundary crossing:

<b>CW elements</b>	<b>Activity theory element</b>	<b>Elements for a collaborative setting for boundary crossing (CW)</b>
Participants as teachers, teacher educators and researchers	subjects of communities	Teachers, teacher educators, researchers and educational stakeholders as subjects of communities
Representatives of special areas	experts of multiple communities	experts as subjects of multiple communities
Key questions or information booklets	Mediating artifacts	educational materials, videos, key questions or information booklets and other physical or mental representations
schools	communities	Multiple communities with boundaries
Work schedule	division of labor	Roles of participants from different communities
Discursive rules for communication	rules	Cultural, social, discursive rules for communication
Curriculum output	Objects	Shared meaning, curricular concepts as object about curriculum innovation

Table 3: Elements of a Curriculum Workshop (CW), activity theory and setting for boundary crossing.

### **Examples of Boundary Crossing from Cases Studies**

In a follow-up project CROSSNET the concept of boundary crossing was introduced expanding teacher professional development as collaboration in different settings among communities of teachers with different school subjects, teacher educators, researchers, administrators and politicians. The project consists of ten national sets with three schools and three teachers in each school in Austria, Denmark, Germany, Ireland, Poland, Portugal and Spain. For each set case studies were planned with national coordinators. In a first stage interviews were conducted about the innovative background of the approach and embedded in this the kind of boundaries and planning of boundary crossing. These interviews were an inquiry about central elements of activity systems for collaborative boundary crossing: Subjects involved and related communities, mediating artifacts, boundary objects for boundary crossing and rules of communication. These elements are

constructive parts of collaborative settings for boundary crossing activities such as a Curriculum Workshop.

In Germany three national coordinators are planning different approaches of boundary crossing embedded in innovative projects mainly about context related science teaching. These projects are called Biology in Context (BiK), Chemistry in Context (ChiK) and Physics in Context (piko). They got first impulses from the Salters project in UK and were politically driven by TIMSS and PISA results. One approach “My subject restricts me” is planning to cross boundaries of the subjects biology, chemistry and physics. Communities are groups of teachers with these different subjects, subject moderators in teacher education, subject advisors and heads of subject departments. They meet in subject groups, project groups or sets. Boundary objects are structural planning aids and a competency matrix. The second approach “Extensive introduction of educational standards” intends to cross science subject and teacher status boundaries. Boundaries are seen between teachers of different subjects and teacher educators. Collaborative settings are planned as Quality Fora with collaborating teams of science teachers and teacher educators. The third approach “From input to outcome orientation in Biology education” defines main boundaries between theory and practice and status levels in the school hierarchy. Communities are teachers, principals and set organizers of the project. Possible objects for boundary crossing in different kinds of collaborative meetings are teaching concepts, guidelines or tasks.

In Spain the project MaterialScience is running for the development of teaching units. They are ICT based, research based, inquiry based and contextualized with the intention to change subject matter in the sense of STS (Science, Technology, Society). Boundaries are identified between teachers and students, the status of normal teachers and teachers with in-service duties and between theory and practice in schools and universities. For boundary crossing in-service teachers can play the role of brokers but more comprehensive partnerships are planned that merge these communities.

The Portuguese approach “EquilibrAction” arises from computer supported university courses about chemical equilibration with the intention to support STS and a constructivist multidisciplinary learning. Boundaries are identified between a restricted and integrated curriculum, representing communities of computer illiterate and computer literate teachers. Mediating tools are simulations, games, web-quest and ICT.

The Danish approach arises from the project CAND developing materials about applied didactics in alternative learning environments. Competing communities are seen as teachers from the teacher training institute CVU, CFU administrators, teachers, technicians and university teachers. From the view of teachers boundaries are between them and the CVU as ivory tower. Boundary objects may be handbooks, internet sites or curriculum resources.

In Austria there are two approaches. One approach is about English as foreign language in science education. It developed from a university practicum for English in science and a project with migrants PROMISE. Communities involved are teachers, teacher educators and university teachers collaborating in team meetings. Boundaries are identified between subjects and school types. The second approach is about the use of videos for quality improvement in physics education. It grew out of a university course with

regional groups, a student practicum and the PROMISE project with migrants. Boundaries are identified through differences of subject teaching and integration. These boundaries are topics to be discussed in team meetings.

The Polish approach is about teacher improvement for interdisciplinary education. Communities involved are scientists in university departments, science teachers, regional educational authorities and authorities in Vojvod centers. Boundaries are identified as different interests between the university and the educational administration and visions for improvement between teachers and the university. The Internet is viewed as a specific tool for mediation to connect communities. Boundary crossing will be institutionalized in a newly planned center for education.

The Irish approach is related to the European project GIMMS about gender aspects in science teaching and a Masters of Education course about mentoring. Boundaries are identified between science and mathematics and between school, university and policy. Boundary crossing is planned in a Curriculum Workshop setting using discursive rules for public exchange.

### **Strategies of Collaboration Across Boundaries**

In the preceding case studies overview collaborative systems of educational communities for boundary crossing are described that have similar elements of boundaries, mediating tools or objects. Boundary crossing in these approaches can be categorized as a transition between subjects, redirecting teaching and learning as standard- and context-orientation, mediation with communicative tools (ICT, videos, foreign language) and collaborative mentoring in teacher design teams. The following description of collaborative issues of boundary crossing with similar elements is a first attempt to develop a curricular process approach for shared meaning making in a public space such a Quality Forum, team meetings, group meetings of projects or departments, seminars or Curriculum Workshops. In these settings for boundary crossing elements for a Curriculum Workshop may be identified and elaborated as in table 3.

#### *a) Crossing subject matter boundaries*

Usually teacher education and classroom teaching in the secondary schools are organized in subjects with separate courses for biology, chemistry and physics. Integrated science, STS or connections among these disciplines or other subjects are an exception.

Boundaries between the subjects biology, chemistry and physics, other subjects, a context of an outside world or applications, between subjects of primary and secondary level, in timetables or between schools and universities are part of a complex system that offers a chance to overcome restrictive boundaries of single subjects. Unfortunately it is not enough to develop new materials or concepts with themes for integration as experienced in the PING project. A systemic view requires in addition teachers with a professional development that enables them to teach these new concepts and to be supported, to change the school organization with rigid timetables or to request a different kind of teacher education in universities.

Subject matter boundaries are discussed by Atkin & Black (2003), the authors of the OECD SMTE study about science, mathematics and technology education in different countries. They offer a wide range of experiences about curriculum integration in this field and the specific boundaries between the science subjects (biology, chemistry and physics) and math or technology. Their final comment is that boundary crossing can be attractive but also sterile and superficial as well. Connections between subjects and the world outside should be tried out relatively early in school. Cross curricular perspectives that mirror the real world complexities are appreciated by most students particularly as they approach adolescence. But they call for resources that no one subject can provide. Separate communities of practice in science should interact and borrow across their boundaries. At the center of these efforts are communities of teachers, researchers, laymen or stakeholder in education that collaborate and create new communities. "Boundaries don't necessarily imprison if one is alert for opportunities to transcend them" (p. 79). But this should be done in a systemic view about a comprehensive curriculum design.

A comprehensive curriculum design with boundary crossing of science subjects is a pretentious work of collaboration, resources and support. It should be anchored in practice that challenges the work of communities in school for good practice without superficiality. A cross disciplinary approach should move forth and back between deep understanding of scientific phenomena and complexities of real world issues. Learning science for its own sake should not be excluded. This means that different communities of practice as described by Wenger (1998) from sciences themselves, from the teaching profession and from stakeholders outside school should work in a team. These communities represent the science subjects as well as a context.

In this sense boundary crossing is not only a domain of subject matter specialists that represent communities of scientists in biology, physics and chemistry or subject teachers. They should connect with educational tracks and field activities (Samonek-Miciuk, 2002) or visits in museums and out-of school facilities and cooperate with educational stakeholders from teacher education, with parents or representatives of business. Students might be involved with different needs, interests and skills that modify a curriculum design for different age groups.

Boundary crossing with representatives from different communities of subject areas and real life settings needs mediation tools (boundary objects) or brokers for mutual understanding and support to enter new terrain in education. Such tools may be elements of a Curriculum Workshop such as an information booklet about a key question of innovation, an agreement about discourse rules or a product. Brokers might be teachers with different subjects, stakeholders of different background from sciences and educational practices or teacher educators with multiple memberships as former teachers, parents or administrators.

Boundary crossing as meaning making is an important step to understand traditional restrictions in subject learning but is not enough for curricular planning and enactment. Activity theory goes beyond meaning making and initiates learning as collective change in education. The transformation of standards in science education is primarily a question of meaning making with different communities of practice with a resulting professional learning process. On the other hand is a change of teaching practice beyond transmission

of subject knowledge, a reform toward informal learning, field activities or innovative professional development as a matter of generic planning of practical change in collaboration according to activity theory. Crossing boundaries of subjects toward context orientation, integration and scientific literacy is therefore at first glance more a matter of collaborative curriculum innovation while the implementation of standards remains in meaning making for educational practice. But as usual in reality both types of approaches mix in practical projects such as Chemistry in Context (ChiK) or Biology in Context (BiK): Here we have the national task to transform national standards as outcomes or competencies and teachers are mainly challenged to make meaning about standards and adapt them flexible to their school practice. But teachers are as well engaged in generic curricular innovation through development of new materials, suggestions in Curriculum Workshops and innovative professional development. Questions arise such as: "What kind of boundary crossing happens in the case of a) outcome/competency orientation or b) generic curricular innovation? Which communities exist (teacher teams, school sets, experts, teacher educators, politicians)? Which kind of meaning making/brokering or interactive setting for generic innovation does exist? What are the roles of representatives from different communities in a Curriculum Workshop or quality forum?"

*b) Boundary crossing in a standards framework*

The implementation of educational standards confronts schools with the task to focus the work on output control connected with new approaches of teaching and learning such as Biology, Chemistry of Physics in context. The constraints of syllabi are now shifted to a higher extent to standards with the requirement to develop competencies, which means a new orientation of educational work for the development of competencies but more freedom in the process of teaching the subjects. This implies new requirements for teacher professional development in the search of adequate teaching materials and methods for competence development. The new context projects are a reaction to these new tasks. They differ in the kind of planning from the other group of projects about crossing boundaries of subject matter, because their frame of reference are standards and not so much subject matter. Within this frame of reference questions arise about the boundaries and their peripheries or edges of communities (Wenger 1998, p. 117; Krohn & Küppers, 1990, p 314ff) and about boundaries of practice within this framework. Peripheries may be a zone of contacts between different communities with a social space of its own, generating new meaning for innovation or shifting boundaries. Boundaries within this framework call for meaning making between traditional communities of subject teachers with communities related to the envisioned context.

As mentioned in the preceding part standards in science education are primarily a question of meaning making with a resulting professional learning process. Within this framework peripheries can be tested for innovation and in addition boundaries of subjects may be crossed toward context orientation, integration or scientific literacy in collaborative curriculum innovation.

This implies the collaboration of two different kinds of communities with different structural tools: At the periphery teachers and teacher educators get into contact with politicians or administrators to interpret and shift boundaries of standards. Within this

framework the kind of communities depends on the context orientation: for applications communities from business, crafting, industry or health services may be of special interest; for cultural or social references groups in everyday life, research, theatres, museums or architecture may be chosen. Possibilities are manifold. Collaborative structures can be at the centre of communities or at the periphery. An organizational setting is a Quality Forum, but can be as well a Curriculum Workshop or a Learning Studio (Lambert, 2003). In all these settings boundary objects need to be developed such as concepts for context orientation, classification of learning opportunities, video clips, questionnaires, collections of information or examples of good practice. Brokers or tour guides as mediators may be defined with multiple memberships in teaching, teachers education and every day life. Teacher professional development is an endeavor with two steps: to develop teaching of subjects in a context and to modify the teaching framework for innovation at the periphery.

*c) Mediation with communicative tools for boundary crossing*

Video, language and computers in schools can be used as tools to improve interaction and reflection in science learning and teacher professional development. In the two Austrian projects videos and language are used as tools to initiate a reflective process about teaching and learning in networks of teachers with different profiles and learning communities of students or combined communities of students and teachers. A Portuguese project uses computational resources in collaborative teacher education for the professional development of a more active, collaborative, multidisciplinary, context-oriented and less abstract style of teaching. These computational resources need to be adapted by teachers and selected for innovative science teaching (STS, context orientation etc.).

Videos, language and computational resources are different in the kind and difficulty of handling but similar as mediational tools. They document linear or interactive information processes as mediation for feedback, reflection and collaboration of innovative learning procedures. The mediational tools can be used separately or in combination: Language and videos for interactive reflection, videos for documenting processes about teaching and learning or specifically with computational resources and computers with a webcam as interactive video.

The use of videos for boundary crossing in teacher education is discussed in the Lambert (2003) articles within the framework of activity theory. Their central arrangement for innovative learning as an interactive process is the Learning Studio, that crosses boundaries over different activity systems. The Learning Studio brings different communities together (teachers, students teachers educators, others) for reflection and collaborative interaction. Videos are used as tools for developing instruments of boundary crossing (boundary objects). They are not boundary objects themselves! Boundary crossing in the first place needs a social arrangement such as the Learning Studio or a group for reflection with different communities or a Curriculum Workshop, where boundary objects for shared meaning are developed. Language and computational resources differ from videos as external tracking systems because they are part of the interaction between communities. As interactive tools they offer different instruments for

boundary crossing such as speech acts, arguments, texts, simulations, games, web-quest etc., that can be used as boundary objects. Bannon & Bødker (2006) view computational resources as boundary objects for sharing items in communities in a common information space. But cooperative work is not simply facilitated by a shared database but must be actively constructed for common meaning in an activity system.

In each case of video, language and computer use learning communities and interactive arrangements for reflection and collaboration have to be defined for boundary crossing. These communities differ depending on the intention of the projects. They can be teachers with different profiles, scientist, teacher educators and students as communities reflecting on improvements of teaching and learning. Boundary objects for these communities can be texts, materials, teaching concepts or computational tools.

*d) Overcoming boundaries through collaborative mentoring in teacher design teams*

The need to develop schools, universities and other institutions as learning communities and science and mathematics teachers as learners and mentors is an attempt to move away from past essentialist epistemology. In Ireland schools have distinctive traditions and cultures with cultural rules and a lot of tacit rules and embodied knowledge. The universities hide behind their bureaucracy. Policy stays remote, a bit too detached and don't get themselves involved. Policy makers need to be brought in to understand what is happening in the process.

For this the Curriculum Workshop or a Teacher Design Team will be used on a number of occasions and in a number of settings: inside each school as a creative space to develop curricular materials; between schools as a forum for discussion and between the schools, university and key policymakers who are responsible for the implementation of the junior cycle science and mathematics curriculum. It will help identify models of partnership in the policy implementation process that may well inform future science and mathematics curricular reform.

Boundaries to be crossed are identified between subjects in the sciences and mathematics, between in-service teachers, between initial and in-service teachers, between theory and practice, between and inside case study schools and between schools, university and a number of key policymakers and stakeholders. They are related to various communities in different settings. These settings are not very much future oriented and innovative since they are traditional, bureaucratic, with tacit rules, not linked, detached and ad hoc informal and lack a driving policy. To make changes you have to be explicit, put the rules to agreement, bring the groups together in a respectful way, mutually to understand each other. CROSSNET will be an incentive for explicit dialogue in a forum like a Curriculum Workshop with groups like Teacher Design Teams, gaining new insights from former programs for transition in school and integrated projects, a cultural broker as project coordinator and critical friends in the project. Boundaries will not be obvious in advance but are a result of the process.

Boundary objects for the development of a shared meaning about innovation in mentoring must be found in collaborative settings like the Curriculum Workshop or Teacher Design Teams with creative trials of arguments, key questions for innovation or

sorting and classifying educational problems for the development of socio-cultural-economic prosperity.

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