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Students' socio-scientific reasoning on controversies from the viewpoint of education for sustainable development

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Abstract In this article, we study third-year university students' reasoning about three controversial socio-scientific issues from the viewpoint of education for sustainable development: local issues (the reintroduction of bears in the Pyrenees in France, wolves in the Mercantour) and a global one (global warming). We used the theoretical frameworks of social representations and of socio-scientific reasoning. Students' reasoning varies according to the issues, in particular because of their emotional proximity with the issues and their socio-cultural origin. About this kind of issues, it seems pertinent to integrate into the operations of socio-scientific reasoning not only the consideration of values, but also the analysis of the modes of governance and the place given to politics.

Résumé exécutif Dans ce travail, nous avons comparé le raisonnement d'étudiants en licence sur trois Questions Socio-Scientifiques controversées dans le cadre de l'Education au Développement Durable: deux questions locales (la réintroduction de l'ours dans les Pyrénées et la présence du loup dans le Mercantour) et une question globale (le réchauffement climatique). Nous nous sommes appuyés sur le cadre théorique des représentations sociales et du raisonnement socio-scientifique.

Sadler, Barab & Scott (2006) ont introduit la notion de raisonnement socioscientifique. Ces auteurs ont élaboré de façon théorique le raisonnement socio-scientifique à partir de quatre opérations souhaitables dans l'analyse des QSS: (a) l'analyse de la complexité inhérente à la question étudiée, (b) l'examen de la question à partir de différents points de vue, (c) la perception que la question doit être soumise à des recherches complémentaires sur le plan scientifique mais aussi social et (d) l'expression de scepticisme vis-à-vis d'informations qui peuvent être biaisées.

C'est à Moscovici (1961, 1976) qu'on doit la réapparition du concept de représentation sociale. La représentation sociale est un processus à la charnière du social, de l'affectif et du cognitif qui forme un cadre interprétatif. C'est aussi un produit, car elle est constituée de croyances et d'opinions organisées autour d'une signification centrale et par rapport à un objet

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donné. Les attitudes, « *clés de voûte* » de la représentation selon Moscovici, introduisent une dimension normative et évaluative à partir de laquelle les informations sont pondérées et évaluées par le sujet. Les individus ont tendance à effectuer des catégorisations sociales en fonction des dimensions les plus saillantes dans le contexte en question. Ils ont conscience d'appartenir à des groupes sociaux, leur appartenance influe sur leurs réactions émotionnelles et évaluatives (Tajfel, 1972). On observe un principe d'accentuation des contrastes (on perçoit les différences entre membres de catégories différentes comme étant plus importantes qu'elles ne le sont réellement) et un effet d'homogénéité (on atténue les différences entre membres à l'intérieur d'une même catégorie). Nous avons étudié les représentations sociales des étudiants sur les ours réintroduits.

Nous avons constaté que sur la question de la réintroduction de l'ours deux opérations n'ont pas été mobilisées par les étudiants: la perception que la question doit être soumise à des recherches complémentaires et l'identification des incertitudes. Deux autres opérations ont été réalisées de façon partiale en prenant le parti pris des éleveurs anti-ours (l'examen de la question à partir de différents points de vue et l'expression de scepticisme vis-à-vis d'informations qui peuvent être biaisées).

Globalement le pattern de raisonnement des étudiants sur les questions de l'ours et du loup est similaire, à l'exception de deux opérations qui ne sont mobilisées que sur la question du loup: le besoin de recherches complémentaires et l'identification d'incertitudes. Si l'on compare les raisonnements sur ces deux QSV locales à celui développé sur le réchauffement climatique, les différences essentielles portent sur la place de la dimension affective et sur l'importance de la gouvernance participative souhaitée.

Les raisonnements des étudiants varient selon les questions traitées, en particulier en fonction de leur proximité affective et de leur origine socio-culturelle.

Dans cette recherche, nous avons observé que plus la « proximité affective » de la question traitée est grande avec les étudiants – question locale impliquante du fait de leur origine socio-culturelle - plus l'apprentissage scientifique (analyse critique de leurs conceptions, appropriation de connaissances, réflexion socioépistémologique sur les savoirs impliqués, raisonnement) est faible. Tant l'emporte la surexpression de l'affect. Si la situation proposée aux étudiants s'oppose à leur système de valeurs, l'affect peut freiner le raisonnement critique, les « aveugler » et constituer une résistance. Bien que la contextualisation soit supposée améliorer la cognition située et favoriser l'apprentissage scientifique en donnant du sens aux savoirs scientifiques, on a vu ici les limites d'une contextualisation locale trop impliquante. Toutefois l'analyse de questions socio-scientifiques locales ou globales dans une perspective de Développement Durable peut favoriser la mobilisation intégrée de concepts interdisciplinaires et promouvoir la citoyenneté scientifique des élèves.

Sur des questions reliées à la perspective du Développement Durable, il semble pertinent d'intégrer aux opérations du raisonnement socio-scientifique non seulement la prise en compte des valeurs, mais aussi l'analyse du mode de gouvernance et la place du politique.

Keywords Education for sustainable development · Socially acute questions · Socio-scientific reasoning · Social representations

Our goal is to analyze students' reasoning about various controversial socio-scientific issues from the viewpoint of education for sustainable development: local issues (the reintroduction of bears in the Pyrenees in France, wolves in the Mercantour) and a global

one (global warming). They were third-year university students. Work today on the teaching of socio-scientific controversies is developing in line with the educational movement called Science-Technology-Society that emerged during the 1970s. In France, a connected field of research has been developed entitled *les questions socialement vives* (Legardez and Simonneaux 2006). This expression is not easy to translate but denotes a field that analyses the teaching of *socially acute questions* (SAQ). These questions may be *socio-sociological* issues like globalization, immigration, unemployment or *socio-scientific* issues including genetically modified organisms, cloning, and cellular phones.

SAQs have implications in one or more of the following fields: biology, sociology, ethics, politics, economics or the environment. They are SAQs when the differences are not limited to the field of science. SAQs are subject to controversies and they are marked by doubts in the reference knowledge and in the social implications. SAQs are the object of controversies between specialists from the disciplinary fields or between experts from the professional fields. SAQs challenge social practices and reflect social representations and value systems; they are considered by society to be an issue and give rise to debate; they are the subject of so much media coverage that the majority of students have, at least, a superficial knowledge of them (Legardez 2006). There is no single valid and rational solution. This does not mean that all solutions are equal.

Expert disagreements about SAQs indicate that there is a debate about the existence of certain scientific criteria, of scientific evidence. Initially defined as a discourse on science, epistemology analyses the process of construction of scientific knowledge. Contemporary epistemology has widened its scope.[1] Science is considered as a social practice marked by conflict, tension, and projects in the social, economic, and political contexts. The sociology of science thus feeds into epistemology. Epistemology then analyses the conditions under which scientific discourse is produced. We take a moderate *relativistic* position, in other words, we believe that there is no a priori structure of the sciences (plural) and that they are social products influenced by internal and external sociability. Sciences (the techno-sciences in the post-modern society) thus include social, ethical, economic, and political constraints that make up the society in which the sciences are produced and that, in turn, act on that society. They *perfom* reality, to use the term invented by Callon (1999). Knowledge of the nature of science affects the analysis of controversial socio-scientific issues. To be able to deal with this type of issue, students have to know how to recognize and interpret data, to understand how different social factors can have different effects and to understand that stakeholders often have diverging opinions (Sadler et al. 2004).

Questions surrounding education for sustainable development

Emergence and controversies

This paper discusses a training situation set up with an education-for-sustainable-development perspective. In economic terms, the dominant paradigm was for a long time that development—regarded as the pursuit of well-being—was inseparable from growth, even for authors like Amarthya Sen (1999). In this sense, development was synonymous with wealth; it was measured by the gross domestic product. At the beginning of the 1970s, the Meadows '*Limits to growth*' report to the Club of Rome sounded the first warning about

[1] Contemporary epistemology is seen as a crossroads discipline grouping together research in linguistics, sociology and history.

the depletion of the planet's resources caused by the economic model; this report also marks the return of Malthusian arguments. The needs of the planet continue to grow because the population is increasing but also because the pattern of development depends on an increasing use of non-renewable resources; beyond demographic control, it is the pattern of growth that should be examined because it accelerates the depletion of resources.

In the 1980s, the very concept of development was questioned with the end of the post-war boom from 1945 to 1973, with environmental degradation and with the impossibility of transferring development to the South. It is the persistence of poverty and the problems of access to care, health, and education that raises the question. Development cannot be reduced to purchasing power; it is necessary to redefine wealth. The Human Development Index is thus considered to be a more pertinent indicator because it takes social and cultural dimensions into account. In these analyses, the targeted social and political conditions necessary to development are analyzed, development is no longer simply an economic concept, it becomes a political science concept integrating ethical doubts, and this dimension leads to a questioning of the justice of the situations. The idea that progress is synonymous with development no longer goes without saying. The notion of sustainable development is only about 20 years old. It is in fact only a new way of looking at the dual questions of economic development from a capitalist point of view and the need to preserve the environment. Sustainable development is not a scientific concept in the sense that it emerges in the political sphere generating guidelines and principles for action rather than a framework for analysis. It was first suggested by the World Wildlife Fund, the World Conservation Union, and the United Nations Environment Programme as the concept of improving the quality of human life while living within the carrying capacity of supporting ecosystems. In the report entitled *Our Common Future* and known as the Brundtland Report submitted by the World Commission on Environment and Development to the United Nations in 1987 and which served as the basis for the Rio de Janeiro summit in 1992, sustainable development is defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs and it is now the commonly accepted definition.

Sustainable development is usually considered to be based on three considerations: (a) environmental, to take the interactions between the environment and human activities into account¸ (b) economic, to find the best way of providing for human needs, and (c) lastly social to take account of the relationships between different societies or social groups, including between generations. In the 1990s, sustainable development became increasingly associated with, certain people would say reduced to, protecting the environment. However, recognition of the generalization of sustainable development by the United Nations would do little to prevent continuing thought on the notion of sustainability. Economic trends were to challenge the very notion of development along with the notion of *degrowth* (Berr and Harribey 2005; Latouche 2006) based on the work of Nicolas Georgescu-Roegen (1972) for whom the pursuit of growth was unsustainable if we take into account the entropy of the system. Criticism of development is also based on anthropological analysis, the development concept in itself being a cultural perception that must be questioned and not applied per se to the planet as a whole. Questioning relates as much to the way so-called advanced societies consume as on the modalities of production. The increase in environmental crises during the 1990s reinforces this idea of economic and social interactions with the environment.

Sustainable development is not only a framework for action; it is an ideology (Simonneaux 2007). Sustainable development consists of political goals (solidarity between generations, protection of the environment, optimal distribution) that can be broken down

into principles for action; the scientific framework of reference is multiple (economic, ecological) and above all less important than the philosophical framework (fairness, irreversibility, solidarity, the precautionary principle). It effectively is a model of society that is proposed and not a framework for scientific analysis; the legitimacy of the discourse on sustainable development is primarily socio-political, scientific demonstration helps support this legitimacy but does not suffice in itself. The socio-political dimension leads us to focus on the mode of governance. Criticism of sustainable development is then, no longer limited to the notion but also to the discrepancy between displayed political principles and the effectiveness of the actions undertaken. Environmental education for sustainable development is France's contribution in response to the *United Nations Decade of Education for Sustainable Development* (June 2003).

Environmental education for sustainable development takes environmental education further, with full consideration for what has been achieved previously. Mappin and Johnson (2005) note that there have been three phases in the way environmental education has changed: (a) in the 1970s, the objective was to change personal behavior; (b) in the 1980s, it was personal change, an understanding of the motivations and personal attitudes which influenced personal decisions; and (c) in the 1990s, the objective had become to change social values and systems in order to protect sustainability and social justice. Recently, in the circular of 2007, the institution has promoted education for sustainable development. We can question the objectives of education for sustainable development as we do the principles of sustainable development. To achieve sustainable development, scientific knowledge is necessary but is not sufficient for decision-making. As well as the cognitive side of the learning process, there are also psychosocial and ethical dimensions resulting from motivations, affects, and the interests at stake. The term *education* is used to recall the axiological perspectives inherent in any environmental, ethical, or political debate as it is hoped that this education will go beyond the simple acquisition of knowledge, towards the support of an ideological way of thinking. Here lies one of the reservations expressed by the teachers of education for sustainable development; but it is also very difficult to define this way of thinking.

Socio-scientific reasoning

Sadler and colleagues (2006) introduced the notion of socio-scientific reasoning. As opposed to formal reasoning based on pure logic, reasoning on SAQs is nonformal because the issues are ill-defined, poorly structured, and because there are no indisputable solutions, because the reasons can support both a point of view and its opposite. Nevertheless, nonformal reasoning is also recognized as a rational process of the construction and evaluation of the arguments (Kuhn 1993). Sadler and colleagues (2006) based their theory on four desirable operations: (a) recognizing the inherent complexity of the issue being studied; (b) examining the issue from multiple perspectives; (c) appreciating that the issue is subject to ongoing inquiry; and (d) exhibiting skepticism when presenting potentially biased information. The authors integrate the question of the uncertainty involved in operations (a) and (c). For our part, we chose to make a distinct operation out of it, associated with that of the risks. It seemed worthwhile to us to complement this reasoning with two other operations: (a) identifying the risks and uncertainties and (b) taking into account the values (potentially marked by the influence of culture, society, or the media) or ethical principles underlying decision-making. In this study we examine students'

reasoning developed about three SAQs from the viewpoint of sustainable development: the reintroduction of bears in the Pyrenees, wolves in Mercantour, and global warming.

Social representations

Our subject here is the social representations of bears as constructed by the students. Moscovici (1976) was the first to reintroduce the concept of social representation, first developed by Durkeim (1878) as *collective representation*. Social representations stand at the crossroads between the social, affective, and cognitive aspects that make up an interpretative framework. Social representation is also a product, as it consists of beliefs and opinions organized around a central meaning attributed to a given object. Attitudes, *keystones* of what Moscovici calls representation, introduce a normative and evaluative dimension, which influence the way the subjects consider and evaluate their information. Attitude is likely to bring out the most affective side of social representations in the form of an emotional reaction to an object. This is also the aspect of social representations (Gilly 1980) that rouses most opposition. Social representations determine behavior and play a prescriptive role by defining what is or is not licit and tolerable in a given social context (Abric 1994).

A social representation is the result of a process involving several stages structured around two poles: objectivation and anchoring. A figure is a representation in its most condensed, visualized, central, objectivated form. Objectivation is the process by which data is turned into concrete images. This process involves three operations: selection of the information (a *filtering* operation), condensation of the information around certain major figures (*figurative nucleus* resulting from an operation of *structuring schematization*), and a transformation of the data retained into obvious realities (concepts become things by *naturalization*). The nucleus providing the image, now that it has become obvious "reality", provides a framework for interpreting and categorizing new information when activation occurs (or anchoring according to Moscovici). The process ends when the social representation itself is formed. The objectivation and anchoring processes are influenced by three factors: dispersion of information, focusing of a group on specific areas of interest, and group pressure on individuals to accept its values.

In parallel to the cognitive process, the socio-cultural origin and the place of the subjects in the social context will both help determine the way they interpret the object. Social representations are "subject to a dual logic: cognitive logic and social logic" (Abric 1994, p. 14). Social representations play a triple role "of enlightening (giving meaning to realities), integration (incorporating new concepts or facts into familiar frameworks) and sharing (providing a 'common sense' that helps define the identity of a social group)" (Moscovici and Vignaux 1994, p. 25). Social representations "include aspects that are conscious and unconscious, rational and irrational. As a result, the word 'cognitive' is not appropriate when applied to social phenomena. It would be better to use the word 'symbolic' which is not at all the same thing" (Moscovici 1996, p. 73). Emotional reactions influence the construction of social representations.

The fact of belonging to a social category, of having a social identity, causes subjects to share the thought processes of the category; but it is not the only thing to influence the way things are represented; socio-professional identity also has a marked influence. The way social representations develop depends on the values shared, which may be different or at least accepted to varying degrees, depending on the social groups. The representation will attribute particular significance to the way these values are ranked and combined. But

social experiences do not exclude personal experiences that allow individuals to forge their own ways of apprehending reality by constantly adjusting their system of representations to the particular situations they encounter. Even if, as explained by Pierre Bourdieu (1980), personal experience cannot differ enormously from one subject to another, since every one tends to consider that his/her own situation is "natural" and consequently to reproduce it rather than to try and gain perspective on it.

The social dimension, determined by an ideological and historical context, transmits an analytical framework for representations while at the same time conveying a value system. These are strongly linked to the value systems of individuals. By assimilating the dominant value system, subjects adopt the dominant ideology and then express it as their own discourse. By this process, the predominant reference system tends to become the overriding force in a value system.

The way a group functions determines the position of individuals in the group, how well they are integrated, how much they adhere to, oppose or remain independent of the group's value system. The social role, which can vary during the individual's life span, has a determining influence on the way subjects assimilate or reject the dominant system of representations. The representations help build a common social reality; they are developed in a social context to which the individual adopting these representations will adhere to a greater or lesser extent. In this sense, they lead us to look closely at the concept of identity because they become an integral part of the way individuals perceive themselves and the group to which they belong. The idea of social representation is related to the way in which a social group is structured relative to an objective. In this sense, social representation can be seen to be more an issue of identity than of conception (Astolfi 1999). This is similar to the view of Dubar (1991) who states that an understanding of the way identities are constructed requires an internal understanding of the representation.

Individuals tend to make social categorizations in keeping with the most obvious characteristics of the context in question. They are aware of belonging to social groups and this feeling of belonging influences their emotional and evaluative reactions (Tajfel 1972). Contrasts become accentuated (differences between members belonging to different categories are seen to be more important than they really are) and similarities are homogenized (the differences between members of a given category are seen as less important).

Some researchers speak of a *structural* theory of social representations, which hypothesizes that there is a dual system: the *central nucleus* and the *peripheral system*. According to Abric and Tafani (1995), the central system has two functions in the structure and dynamics of the representation. There is an organizational function that determines the nature of the relationships between the elements of the representation; and there is a generating function that determines the significance of each element of the representational field. The central nucleus may be thought of as a stereotype, produced by the process of representational stereotyping. The peripheral system allows the representation to be anchored in the reality of the moment.

Scenario for reasoning

The societal context 1: Sheepherding in the Pyrenees and the introduction of bears

In the early 1990s, the last bear disappears from the central Pyrenees (Fig. 1). Only seven or eight individuals remain in the western core and the extinction of the bear in the

Fig. 1 Idyllic villages in the Pyrenees have become the focus of the debate about the reintroduction of bears and the protection of wolves

Pyrenees thus seems inevitable. The reintroduction of the bear in the Pyrenees is carried out within the framework of a European Union LIFE programme that finances, amongst other things, the capture, transportation and release of the bears. In 1996, three bears are captured in Slovenia to be released in the central Pyrenees:

- Ziva is released and during the winter 1996–1997, she produces two male cubs (Kouki and Néré). Two cubs are born in 2000 and two more in 2002.
- Melba, gestating, is also reintroduced in 1996. She produces three cubs in the winter of 1996–1997. One of them is found dead in July 1997. And on 29th September 1997, tragedy occurs: a young hunter, intimidated by a charging Melba (who is accompanied by her two cubs) shoots her dead. The two cubs, Bouxty the male and Caramelles the female, survive. Caramelles will go on to produce a cub in the winter of 2000–2001 but the latter's dead body is later to be found in the area of Ariège.
- Pyros, a 9-year-old male weighing 235 kg, joins Melba and Ziva's new world on 2nd May 1997

The three bears are wormed to avoid bringing new diseases into the Pyrenees. Biologically, results seem positive. Economically, various local structures in favor of a harmonious development of economic activities in mountain areas, lend their support to the introduction of policies that will help reconcile human activities with the necessity for environmental protection and nature conservation. They hope to see an increase in ecotourism and an enhancement of the local economy.

But opponents of the bear, particularly the sheep farmers, often emphasize the lack of "social acceptance" evoked in connection with the continuing reinforcement of the bear population. Yet, the bear is an animal that has long been part of the Pyrenean culture and heritage. Bear handlers existed up until the middle of the twentieth century. But over time, the bears have more and more frequently fallen victim to hunters.

Since the killing of Canelle (the last female of Pyrenean stock), the situation has become critical for these bears, today so few and far between. The French government

reintroduced four new bears in 2006. Even with this reintroduction, the sustainability of the bear population in the Pyrenees cannot be guaranteed.

There is enormous controversy over the continuation of this reintroduction. The 2006 releases were carried out under heavy police protection, at night, while keeping the exact location of the releases secret, to avoid the violent reactions of anti-bear activists. Anti-bear shepherds have even set traps containing honey laced with shards of glass.

According to anti-bear activists, the bear is a predator, responsible for the deaths of 200 to 250 ewes per year. But defenders of the bear retort that out of the 250,000 ewes present in the mountain summer pastures, 20,000 to 25,000, die each year. Pro-bear campaigners declare that for the anti-bear activists, accepting available subsidies and means of protection amounts to accepting the bear. So, they refuse to protect their flocks while pocketing the financial aid, even if this means sacrificing a large number of ewes: sacrifices which are sometimes arranged and revealed to the press, in order to create a wave of public sympathy (say pro-bear campaigners).

According to opponents of the bear, the authorities did not take the opinions of the population into consideration.

Bear defenders point out that the State organized a large-scale consultation in 2005, "The Pyrenees with the bear". They claim that those against the bear did not attend and, for the most part, boycotted the meetings and later complained vociferously that they had not been consulted. Anti-bear activists are adamant that the bear is a danger to man. Incidentally, they accuse the reintroduced bears of being a potential health hazard. For opponents of the bear, pastoralism-predator coexistence is illusory and the subsidized methods for protecting flocks (animal enclosures, guard dogs, electric fencing) ineffective. Pro-bear campaigners of course contest this. Anti-bear activists denounce a waste of vast amounts of public funds. The budget for the population reinforcement programme 2006 adds up to 2,246,818 euros; that is 45,000 euros per bear.

Regarding the question of biodiversity, the anti-bear groups declare that the brown bear is not an endangered species worldwide and that its presence in large numbers could threaten Pyrenean biodiversity. The Minister of Ecology and Sustainable Development replies: "It is exactly the same thing for the bears as for the most modest of endangered plants or for the least common of insects present within our national boundaries. It does not matter that viable populations still exist outside our borders. We remain responsible for maintaining our own. In this area, no biologist or treaty has ever recommended haggling "you take the bear, I'll keep the insect, you take the panda, I'll keep the whale etc." For the pro-bear campaigners, guaranteeing the long-term survival of a species like the European brown bear is achieved precisely by protecting several stable groups wherever the species is still present. According to the minister, there is only one alternative: either to assume the responsibility of consciously programming extinction, or choosing population reinforcement. A calculated, accompanied and assessed reinforcement.

Controversies oppose pro and anti-bear groups on the subject of diet (Fig. 2). The brown bear's dentition, claws and digestive system reveal him to be a carnivore with leanings of a recent herbivore. Considered as an opportunist omnivore, he eats whatever he can find easily, according to the seasons (raspberries, blueberries, grasses, acorns, beechnuts, chestnuts, insects, dead animals, domestic or wild mammals…), with an average of 70% plants. In the Pyrenees, shepherds tend to regard the bear as being carnivore, but the study of his diet shows his polyphagy and his taste for a variety of foods.

It gets his spring protein ration by eating herbaceous plants, and less frequently dead animals. Roots provide trace elements. From the beginning of summer, he feeds on pulpy

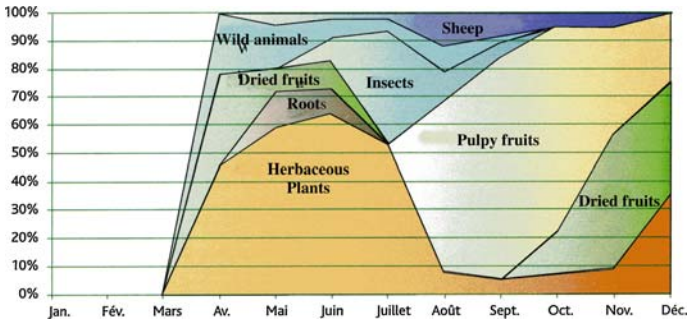

Fig. 2 Annual diet of the brown bear in the Pyrenees (according to the Programme for the reintroduction and conservation of the bear in the French Pyrenees 2006–2009, Ministry of Ecology and Sustainable Development)

fruits (blueberries, alder buckthorn, raspberries etc.), until the onset of autumn and the appearance of dried fruits and nuts (acorns, beechnuts, chestnuts…). During the summer months, he also feeds on domestic or wild ungulates that provide him with animal protein. Predation of domestic ungulates concerns essentially sheep. In the Pyrenees more than 90% of all injuries involve sheep.

Traditionally, agri-pastoral farming is essential to human activity, the economy and the landscape in mountain territories (Fig. 3). Adapted to high altitude grazing, transhumant herding or pastoralism is practised in the vast mountain and high mountain areas where it is one of the rare farming activities. Pastoralism is also practised at medium altitudes beyond the farm holding. Farming units on the summer grazing pastures and on farmlands in the valleys are therefore very closely linked and the conditions in which the activity is practised, determines the future of the farm structure as a whole. Pastoralism plays a social and economic role by maintaining an activity and jobs in difficult areas and contributes to quality products like cheese or meat some of which carry an official label guaranteeing a

Fig. 3 Sheep stations in the high Pyrenees mountains are isolated

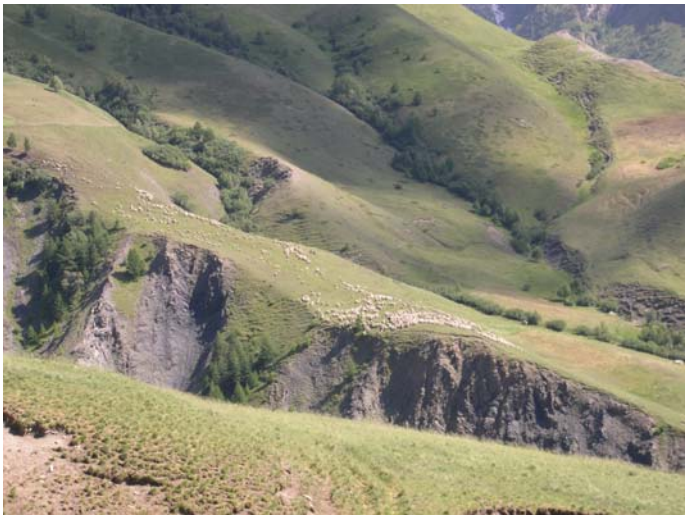

Fig. 4 In contrast to Italian practices, where sheep are raised for milk, French sheep are raised for meat and therefore are not controlled everyday

quality standard or a controlled origin (AOC "appellation of controlled origin", label rouge "red label" etc.).

Pastoral activities also play a fundamental role for the environment by ensuring the care and upkeep of the open countryside and its biologically diverse ecosystems (Fig. 4). Ecological diagnostics of mountain sites clearly reveal that maintaining pastoral activities is hugely important for preserving biodiversity (sustaining diversity in mountain areas in particular by limiting the progression of ligneous vegetation). These activities have a positive impact on the occupation and land use planning in these areas. They also contribute to actively protecting forests from fire. Pastoralism in mountain areas is inherently faced with extra costs compared to farming practiced in other conditions. It also provides environmental services (upkeep of the countryside, prevention of avalanches, maintenance of biodiversity). Furthermore, it faces specific constraints linked with the presence of the bear. The transhumance from June to October makes extensive use of summer pastures under collective management, 550,000 hectares representing half of all French mountain summer pastureland. The 5,300 pastoral farm holdings (inventoried in 2004) represent 35% of farms in the massif. Since 1988, the number of pastoral farms has decreased by roughly 30%.

Attacks by bears are a real problem for the shepherds concerned. Extensive sheep farming leaves flocks vulnerable to attacks by predators even more so because of an evolution towards shepherding without permanent supervision of the flocks. Public authorities, aware of the difficulties facing pastoralism and the importance of this activity, have designed, in conjunction with the farming profession, a pastoral programme for the Pyrenees. This programme offers financial help to equip the high summer pastures (huts, sorting parks….). Compensation is paid for any harm caused by bears and measures have been proposed which aim at limiting damage to flocks. Emphasis is placed on the permanent supervision of flocks by a shepherd, the use of "patous" (the Pyrenean Mountain Dog raised with the sheepfold to ward off predators), and pens with electric fencing to protect the animals. These measures help to reduce the number of attacks by bears and other predators (stray dogs, foxes, etc.).

However, the agri-pastoral world is not unanimous on the issue of keeping the bear. There are sheep farmers in favour of the bear who consider that a shepherd should watch over his flock and that in a way it is thanks to the presence of predators and the absence of fencing that his job exists. They consider that the bear has simply exacerbated preexistent problems. Other professionals who work in mountain areas, especially in cottage industries and the tourism sector, are in favour of the bear's presence. So, he is considered as giving a positive image of the Pyrenees to tourists.

A survey conducted by IFOP (a major French polling organization) in February 2005, on the basis of a sample representing 906 people, shows that for 65% of inhabitants in the mountain zone of the central Pyrenees, the species of animal which best represents the Pyrenees is the bear, the izard (Pyrenean chamois) comes second with 19%. About 71% of those interviewed were in favour of keeping the bear population, 62% were in favour of releases of new bears if it were necessary to the conservation of the species. This survey confirms the results obtained in 2003 (IFOP poll): 88% of French people and 86% of Pyreneans considered the bear to be part of the Pyrenean heritage. 58% of Pyreneans and 72% of French people were in favour of reinforcing the population should it become necessary safeguarding the species.

The societal context 2: Wolves in the Mercantour

After having disappeared from the French countryside in the 1930s, the wild wolves are back and have given rise to a lot of debate. But, how did they return to France? This question is crucial for their opponents. Indeed, the *Canis lupus* species has been protected by law, within the framework of the Bern Convention, since 1993; the date of the signature of a decree that added the wolf to the official list of protected species. This addition to the list is only valid in the case of a natural return of the wolf. Consequently proof that the wolf was reintroduced by man, could lead to a loss of its protected species status. This of course places substantial stakes on this issue.

The first two wolves were spotted in 1993. The coincidence between the date of this sighting and the addition of the species to the Bern Convention has raised a certain number of questions. Did the wolves "naturally" return to France from the Abruzzo region in Italy or were they reintroduced by way of a covert "release"? The hypothesis of a natural arrival is founded on a return of the wolves from Italy, where they have never been totally eradicated and have been protected by law since 1976. The theory is based on the geographical spread of Italian wolf populations: in fact among wolves, each pack has a territory the boundaries of which are determined by the abundance of food. This behavior pattern ensures a natural regulation of the number of wolves present in any given area and leads to the migration of certain individuals in the case of a population increase. Since 1976, the number of wolves on Italian territory has quadrupled (increasing from fewer than 100 to over 400). The wolves have therefore begun a process of recolonization from the Abruzzo National Park. This theory is also backed by several arguments: firstly, the Apennine Mountains constitute a significant vector for geographical spread thanks to the low human population density and the abundance of wild ungulates which are prey for wolves. Secondly, the wolf's capacity to cover great distances (over 100 km in several days) could explain a discontinued colonization. Finally, the successful adaptation of French wolves to their new territory makes a hypothetical release of previously captive animals (in practically constant contact with man) very unlikely.

The reintroduction hypothesis is based on the fact that the wolves could not have arrived in France of their own accord and that they therefore settled in thanks to human

intervention. The main argument to support this theory is the lack of proof of the wolf's passage between Genoa and Mollières (the place where the wolves were spotted in 1993), about 150 km apart. The idea is backed by the fact that humans occupy this zone. Yet, whereas the presence of humans within these 150 km may well be a hindrance to the spread of the wolf, it does not allow us to rule out the passage of the wolf. In Europe, certain wolves feed on waste produced by human activity; to say that wolves cannot approach areas inhabited by man is therefore not always justified.

At the same time, there are rumours of a possible clandestine release. These rumours are based on several arguments or ideas: the economic interest in the presence of the wolves in the Mercantour National Park (certain communities in the Abruzzo region in Italy have developed local tourism thanks to the wolf), the wolves may also have been reintroduced in order to regulate the number of ungulates in the Mercantour National Park.

The "natural" return of the wolves can only be contemplated if the wolves spotted in Mercantour are indeed of Italian origin. This is why a genetic investigation was requested. The University Joseph Fourrier of Grenoble carried out analyses of the mitochondrial DNA sequences of samples taken from different wolf corpses. The results confirmed that the French and Italian wolves are closely related which means that the theory of a release of wolves of non-Italian origin is unfounded and would imply a clandestine capture in the case of the reintroduction by man. If a "natural" return is therefore genetically plausible, only reliable evidence of their presence in all the areas separating the Abruzzo region from Mercantour can confirm a natural arrival. Such evidence is very difficult to obtain because of the wolf's extremely discreet nature. A natural arrival is therefore possible but not proven. The question of how the wolf returned thus remains unanswered and no theory can be ruled out.

Agri-pastoral farmers are against protecting the wolves; some do not hesitate to resort to killing them. This does not reflect the general opinion of the French population. In 1995, a survey carried out by SOFRES (one of the main French polling organizations), representative of the French population over the age of 15, revealed that 79% of French people regarded the return of the wolf as *"good news"*.

The course

We set up a training course to encourage students' socio-scientific reasoning. These students followed a degree course in ecology, agronomy, territory, and society. Our aim was to analyze the positions taken by the students, and the various scientific, economic, political, ethical, cultural, and other arguments, as well as the way these evolved during the course using this more developed model of socio-scientific reasoning. We tried to determine whether other operations should be included in education for sustainable development. The course in ecology, agronomy, territory, and society includes a module on SAQs. Twelve students took this module in September and November 2006. Prior to this course, all these students had taken an agricultural training course for at least 2 years after their baccalaureate (a BTS), followed by a 1-year foundation course or 1 year of another degree course. But, the baccalaureate courses they all followed were very different; environmental protection and management with an environmental bias, or animal or plant production with a technoeconomic bias. We assumed that the question of the reintroduction of the bear would cause debate between these two groups with different centers of interest: ecology/agronomy, two fields which coexist in the degree course.

A. In the first 3-h session, students were initiated to this subject through the emblematic example of GMOs. After studying the dangers and controversies associated with GMOs,

the students analyzed converging and opposing accounts of the production of golden rice (transgenic rice with enriched vitamin A content). We then applied socio-scientific reasoning in its more thorough form (with six operations) to the case of GMOs.

B. The module on the SAQs then continued with the study of a socio-scientific issue: the reintroduction of bears in the Pyrenees. This sequence was divided into five steps during a 3-h session:

1. A written answer, with reasons, to the question: Is the reintroduction of bears in the Pyrenees a contribution to sustainable development?
2. An analysis of short discourses representing different sides of the scientific/environmental, economic and sociological arguments. The passages were taken from projects carried out by other students on this theme, while following the same degree course during the previous academic year. They correspond to media extracts accessible to the students. They are of varying types and degrees of popularization:
   - excerpts from an article called "Ours de fiel, ours de miel" (literally, Bear of bile [i.e., bitterness], bear of honey) from *Terre Sauvage* (pp. 24–29, No. 172, May 2002), a magazine with ecological leanings. Selected extracts by the journalist Fabrice Nicolino or quotes he takes from shepherds or from a member of the bear monitoring team;
   - extracts from an interview with a shepherd conducted by Anne-Marie Siméon for the newspaper *Sud-Ouest*, 3 November 2005;
   - extracts taken from a website (http://www.pyrénees-pireneus.com), which promotes different aspects of the Pyrenees. In these extracts, a researcher at the Centre National de Recherche Scientifique describes different elements in a report for the Ministry of Ecology and Sustainable Development.
3. A written justification of possible changes of position (reinforcement, withdrawal, adjustment, etc.) after reading these articles.
4. Debate
5 A written justification of possible changes of position (reinforcement, withdrawal, adjustment, etc.) after the debate.

Between sequences B and C (see below), the students produced a file consisting of conflicting articles on the wolves in Mercantour and global warming. They were told to analyze the social and physical situation in the discourses (Who is speaking? When? To whom? What are the stakes?), then to analyze the conflicting arguments (What are the differing points of view? On what are they based? Which arguments are the most important? Is further information necessary before being able to voice an opinion?). They also had to justify their points of view.

C. During the third sequence, the work on the controversies in question (wolves and global warming) was presented orally with the help of power point presentation. They were also asked to produce and to comment on a power point a grid to analyze a SAQ. The class as a whole was able to interrupt and interact during this last sequence.

The aim of this last part is to identify if the students transfer the phases of socio-scientific reasoning, if they transfer them more easily to the subject of the wolf (SAQ on a local scale on a theme similar to that of the reintroduction of the bears) than to the subject of global warming (SAQ on a global scale), and if their reasoning on the presence of wolves in Mercantour is similar to their reasoning on the reintroduction of bears in the Pyrenees. Sadler et al. (2006) observed that pupils transfer their reasoning more easily to a theme which is similar to the one used in the teaching material. As in all teaching

situations, the didactic, media and social (even professional) environment must be taken into account as it can interfere with the conceptual evolution of the students which does not occur in a total social vacuum. Here a didactic environment must be reported. A different module, concerning the study of a local agrifood chain, included two days studying sheep-breeding to meet the standards of an official label in the valley of Barèges in the Hautes Pyrenees department, during which time the students met different stakeholders in the local sheep production chain. It is important to underline this, as we shall see that it reinforced the students' reasoning and positions.

The group's social representations concerning reintroduced bears

Fewer than 10 bears remained in the Pyrenees at the beginning of the 1990s, after having been hunted for several centuries. To save this population, bears from Slovenia were deliberately reintroduced on several different occasions. The reintroduction of bears in the Pyrenees is a SAQ, in the sense that the local and national pro-bear and anti-bear movements have sometimes clashed quite violently on the subject. The media have often reported on demonstrations and bears released in the dead of night. Some contests the scientific, ecological justification for the reintroduction, of "maintaining biodiversity", and it is also argued that it has negative socio-economic repercussions on sheep and cattle breeding. Some say that as a predator on sheep, bears will bring about the disappearance of pastoralism and make the Pyrenean countryside inaccessible. For others, not enough bears are being reintroduced to maintain the population. Some argue that bears are primarily vegetarian (eating berries, nuts and roots) or that they eat mostly ants and that it is not bears but dogs that are attacking flocks. Some add that since bears mostly scavenge for their meat, they help to restrict the expansion of epidemics among animals by consuming sick animals and tainted cadavers. Others again suggest that bears should be reintroduced along with other key elements of the ecosystem such as the ibex, which has also disappeared from the Pyrenees. When it comes to socio-economics, some argue that the image of the bear will favor the development of the tourist economy while others complain that its presence will drive tourists away.

According to the sociogenetic model of social representations developed by Moscovici (1961), we generally find at the origin "an innovative social situation, an unknown phenomenon or a conflict between groups…. Comprehensive knowledge on this subject is impossible as it is so dispersed (such a situation is qualified as *information dispersal*" (Vidal et al. 2006, p. 19). Due to a *presumptive pressure* linked to the need for a better understanding of a new phenomenon, a majority position emerges in the group. There is a *focusing* on a particular aspect according to the expectations and leanings of the group. The reintroduction of bears in the Pyrenees generates a new social situation that disrupts the activities of the shepherds and leads to a clash between pro-bear and anti-bear groups. How do the students perceive this reintroduction?

In the first response supported by arguments, all the students declared that they were against the reintroduction of bears. Three admitted to having been in favor before their meeting with the anti-bear shepherds. All were convinced by these shepherds and accepted their arguments. The central nucleus of the social representation of bears in the group seems to be based on the distinction between the Slovenian bear and Pyrenean bear. We may summarize this as follows: man fed the Slovenian bears reintroduced, so they are not naturally frightened. They are potentially dangerous predators for man and shepherds cannot defend their flocks against them. This is in contradiction with the social

representation of the "authentic" Pyrenean bear that flees man. "When we had only real Pyrenean bears, they ran away at the slightest noise but now they come back in a matter of minutes" and "It no longer makes sense to talk about 'the man who saw the bear'."[2]

It would appear that the group of students shared a common social representation about the reintroduced bear and the expression of argumentative variants on the periphery. The question becomes a hot controversial issue through empathy with a single category of stakeholders (the anti-bear shepherds). The social representations of the reintroduced bear leads the students to assume that the reintroduction of bears is intolerable in the context of Pyrenean pastoral activities. While objectivating and anchoring the social representation, they concentrated on one social group based on specific interests, the group of shepherds. Their socio-cultural origins determine the way they interpreted the object, "reintroduced bear". The agronomic training prevails for all the students, even those who did the baccalaureate in environmental protection and management. They made social categorizations: the shepherds (considered to be universally anti-bear, even though there are groups of pro-bear shepherds), the tradesmen of the valley, the professionals of the tourist sector, the tourists, the ecologists and the politicians. They tend to accentuate the contrast between the interests of these categories and to ignore the differences between the shepherds. They only listen to the arguments of the anti-bear shepherds and voluntarily ignore any pro-bear arguments. They identify themselves with the anti-bear shepherds who are against Slovenian bears. It must be said that symbolically speaking, the Pyrenean bear, perhaps because he stands upright, is a myth closely related to man and present in numerous tales: *Le Moussu* (the Gentleman), Martin *courailhat* (the vagrant) or even *pedescaous* (barefoot). In certain tales, he is alleged to have abducted women.

Socio-scientific arguments on the reintroduction of bears from a sustainable development point of view

We examined whether the students based their arguments on the different operations of socio-scientific reasoning and if so, how?

Analyzing the inherent complexity of the issue studied

The analysis of sustainable development requires an integration of the economic, social, cultural, political, and ecological factors. Students are faced with a controversial socio-economic-environmental question of a complex nature. To analyze the question from a social representation perspective, it would be necessary to resort to a systemic approach in terms of connections, relationships, and contexts. The students did indeed take into consideration the interactions between the sociological, economic, and environmental dimensions of sustainable development with a systemic analysis. But the phases of reasoning can be broken down for a better analysis into the socio-economic dimension on the one hand and the environmental dimension on the other.

This breakdown gives a false impression of linearity in the reasoning. It is only the effect of our presentation. If the students' reasoning is entangled and interlinked, we cannot identify any real analysis of the complexity of the issue. The students perform more of an interdisciplinary analysis than a complex systemic type of analysis.

[2] This expression referred to anybody who boasted about it because it was considered most unusual to see a bear.

Two types of environmental reasoning were constructed: reintroducing bears and increasing biodiversity *versus* reintroducing bears and reducing biodiversity. The first argument can be illustrated by this quote: "This isn't sustainable development but an increase in biodiversity, conserving a heritage, a local identity." However, most of the students considered that the Slovenian bear had nothing to do with the local heritage. The second argument can be illustrated by the following questions: Is there no better way of protecting the species in the Pyrenees? What about the bearded vulture or the capercaillie (wood grouse)? These species benefit indirectly from the pastoralism that the bear threatens. The first depends on it for food, the other for cleared areas from which it can take off. Would we not be guilty of favoring certain species to the detriment of others? Sustainable development? But the brown bear is not in any danger globally! Where is the biological evidence that this reintroduction is necessary? The second argument carried the day for all the students.

Two types of socio-economic arguments were used: reintroduction of bears and destruction of pastoralism *versus* reintroduction of bears and development of tourist activities. The first argument triumphed. The first argument can be illustrated by the following quote: "It just isn't fair on the shepherds; the bears traumatize and kill their flocks." The second argument can be illustrated by the following quotation: "The idea of bears can be used to promote local products, it can attract the general public." However, when the reasons are analyzed more closely, it may be seen that the socio-economic repercussions on one category of stakeholders (the anti-bear shepherds) were considered to be more important than any environmental repercussions. The negative socio-economic consequences were exaggerated.

The argument was not unfounded but remained somewhat dichotomous; the students felt driven to decide either in favor of or against the bear, no one formulated other hypotheses or more complex alternative questions such as: under what conditions might the reintroduction of bears be possible? How can the impact of the reintroduction of bears be evaluated? Their systemic approach to the question mainly concerned the organization of life in this Pyrenean valley, sometimes taken to the level of the region or the state. In this case it was in order to criticize the decisions imposed by the region or the state without the involvement of the people of the valley. But they did not go as far as to suggest ways in which such consultation might take place.

Examining the issue from multiple perspectives

The students analyzed the points of view of the different human stakeholders (shepherds, professionals from the tourist industry, tradesmen, tourists, politicians) and animals (domestic and wild): "Bears used to be part of the image of the Pyrenees (it's still widely used). Nowadays, it is a reality and no one wanted, wants or will want to accept it because the reintroduction of bears in the Pyrenees in this fashion condemns all the stakeholders in the shorter or longer term: farmers, tourists or local inhabitants." But they give considerable credence to the point of view of the farmers and only to farmers who are against the bears.

Skepticisms

The students were very skeptical about the scientific data mentioned in the press reports, but they did not challenge the experts themselves. "It can't be true that 70% of a bear's diet is made up of berries, it would be obvious if it were." They had complete confidence in

what the shepherds said, however, without being at all skeptical about their arguments. They all accepted that the Slovenian bear has a different attitude to man, without attempting to verify the source of this claim or whether it is true. An anecdote related by a stakeholder, even at second hand, was treated as a scientific fact: the fact that one bear came close to men in order to catch animals is taken as proof that Slovenian bears have fundamentally different behavior, with the implication that this must be genetically-based.[3]

Identifying risks

The students identified the following risks which to them appeared to form a causative chain: bears attack sheep which causes a regression of pastoralism which causes the countryside to return to a wild state which increases the risk of fire and a reduction in biodiversity which makes the countryside less attractive to tourists. "If bears come back then that's the end of pastoralism, the countryside returns to the wild and the danger of fire increases. Is that sustainable?" Bears are going to attack people, tourists in particular. "Local people are already afraid to go up into the mountains and the problem is even more serious for mountaineers." The students seem to have no doubts on the matter. They do not express uncertainty. However, in these complex systems, there are numerous sources of uncertainty. Some of these sources can be reduced with further data and research; others cannot be, above all in socio-ecological systems, such as the case we are dealing with here. In this type of situation, some irreversibility can occur. This is, above all, what the students perceive.

Stating values explicitly

The students expressed their feelings about how the sheep must suffer, associating this with the sufferings of the shepherds. The shepherds cannot tolerate the sufferings endured by their animals. The relationship between farmer and farm animal is ambiguous, complex and paradoxical and is indeed the object of sociological research around the idea of "shared suffering" (Porcher 2002). Porcher makes a distinction between breeders and producers. The latter practice intensive breeding inside buildings and produce "animal material" for the agrifood chain; their relationship with the animals is reduced to one of power in an atmosphere of cold indifference. In the breeders' representations, the relationship with their animals is a "giving" one: they give to the animals by ensuring their protection and their food; the slaughtering of the animals is their legitimate reward. This "giving" relationship is destroyed in industrial farms. In the context of Pyrenean pastoralism, it is the breeders, the shepherds who look after the flocks. They accept their animals' deaths as the purpose of their profession, as long as they have respected and protected their animals. The animals thus form part of their family heritage; they are an integral part of their identity as breeders. The breeder cannot tolerate the idea of his animals being massacred by bears, or State representatives when there is a risk of an epidemic (Porcher 2007). The students analyzed the relationship between farmers and domestic animals but not the relationship between man and endangered wild animal species. On the other hand, they did not consider biodiversity to be a justifiable value.

This situation will have serious psychological consequences on the shepherds who may lose their situations. "It's very hard on the shepherds psychologically: they'll all have to leave the valleys one after the other." "It's dangerous for the inhabitants, tourists, all those

[3] One can question whether this point of view reveals an unconscious expression of a form of racism.

who play a role in the life of these Pyrenean valleys." "This is their work, this is how they make their living (farming)." The students complained about the way local people were not consulted. "This is a decision made in high places taken without consulting local people." "It's an unbearable imposition: it's barefaced dictatorship." The students call for a *dialogic democracy*. According to them, this mode of governance should prevail during the definition of the code of action of the sustainable development.

The impact of the extracts from opposing texts

The extracts from opposing texts had no impact on the central argument and the rejection of the reintroduction of bears. The students admitted to slight changes in their point of view after reading the texts. For instance, where one argued in favor of introducing other species at the same time: "The bear should be reintroduced at the same time as other animals such as izzards that interact with bears in the same biotope." Another opposed this idea on behalf of the shepherds: "If they were all to be reintroduced (the izzard, the wolf, the lynx), how much room would be left for farmers?" One student recognized the fact mentioned in the extracts that pastoralism was already in decline before the reintroduction of bears.

Sustainable development understood on the scale of a farm holding

The students focus their analysis of sustainable development on the level of the organization of the farm holding and neither on the local level including all categories of actors, nor on the regional or national level. A sustainable farm holding is viable, liveable, transmissible and reproducible (Landais 1998). According to Landais, when referring to the sustainability of the development of farm holdings we can say the same thing as is said about the reproduction of any open system: it is the result of the way the farm interacts with its environment, in the broadest sense of the term.

He organizes these interactions under four main headings (Fig. 5): (a) economic interaction relating to the market; (b) social interaction relating to the integration of farmers and their families into the mainly local non-commercial networks, relations with other farmers as with all the other social actors; (c) bonding between generations which is a particular dimension of social interaction singled out by Landais because it relates both to one of the foundations of the family farming system, the passing down of farms from one generation to another within the family and to the ideal of solidarity between generations which is at the heart of the definition of sustainable development; and (d) ecological or environmental interaction, finally, relating to the connection between the farming activity and the resources and natural habitats with long-term renewal of natural resources as the main challenge.

These students are worried about the *viability* of the Pyrenean farms. This *viability* is partially linked to making secure the system of production that "relies on its techno-economic results but also on the global qualities such as its autonomy, its more or less diversified character, its flexibility and its sensitivity to all kinds of unforeseen events." The situation of the shepherds faced with the reintroduction of the bear is psychologically unbearable for them. Still according to Landais, the *liveability* reveals the quality of life of the farmer and his family, which depends particularly on the "mental burden related to the ability to master the functioning of the system, and to come to terms with the risks incurred, the stress, the workload, the obligations, the hardness, and conditions of work, the physical risks in certain cases." The *transmissibility* of these farms preoccupies the students, not, as is often the case, because of the financial problems of succession related to

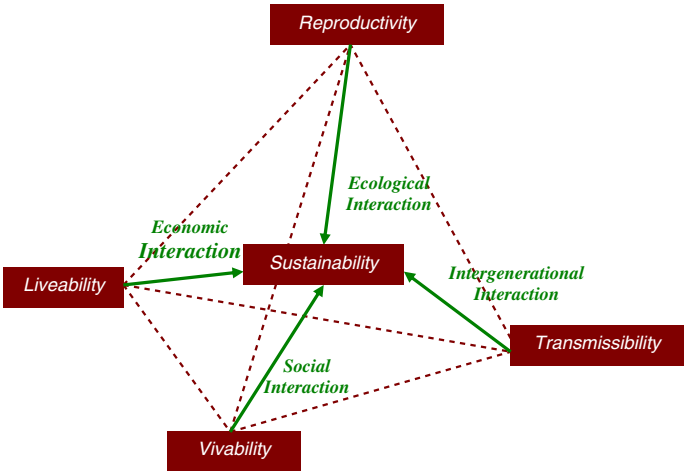

Fig. 5 The four pillars of the sustainability of farms (according to Landais)

the buying back of fixed assets, but quite simply because these farms will no longer be viable. Finally for them, the environmental *reproductivity* is in danger because of the abandonment of the land associated with the disappearance of pastoralism, but also with rural tourism.

Transfer of reasoning to the themes of the wolf in Mercantour and global warming

The wolf was hunted and had completely disappeared from France reappeared in the Mercantour mountains, south of the Alps. The currently observed return was said to be the result of a "natural" migration of wolves crossing the border from Italy (Fig. 6). As with the bears in the Pyrenees, the presence of the wolf is challenged by shepherds and defended by environmentalists.

Comparison of the reasoning on the reintroduction of the bear and the presence of the wolf in Mercantour

Some arguments about the wolf and the bear are similar, others are different. First, students develop an interdisciplinary analysis of the presence of the wolf in Mercantour. Faced with questions on the wolf and the bear, the students blame a drift towards a hypertrophy of the ecological sensitivity of sustainable development. They identify with the local shepherds and have empathy with their concerns. They criticize the modalities of governance that dominate: institutional decisions are not discussed with local actors; they are imposed "from above" (they even use the expression top-down borrowed from their ecology classes to define a research method). They highlight the question of the future of pastoralism. This activity is already in decline; the bears and the wolves will help finish it off altogether. In their view, this question is to be linked to the decisions taken at the level of the Common Agricultural Policy.

The positive impact on biodiversity is considered to be predominant as far the wolf is concerned. But, they wonder about the prey/predator balance: "In the end the number of

Fig. 6 Wolves "naturally" migrated into the Mercantour mountains coming from Italy, whereas the bears were transported into the Pyrenees from Slovenia

ungulates will increase further as the wolf population grows, because wolves eat more sheep than ungulates." "An increase in the wolf population will regulate the number of ungulates." They admit that, as a predator of sick animals, the wolf may have an impact on natural selection. They clearly expose the lack of research to back this issue up. Whereas they challenge the available information on the bear's diet, they ask questions about the diet and the feeding habits of the wolf. Instead of being skeptical about the possibly biased information, they display scientific doubts. They consider that the presence of the wolf may have a positive impact on tourism, which is not the case with the reintroduction of the bear; even though they make a careful analysis of the symbolism attached to the wolf based on psychological studies on the *fear* of the wolf as an *archetypal emotion.* They admit that the wolf has a scapegoat status: by associating it with the devil, it is a symbol of evil that must be destroyed to rid ourselves of a fear of divine wrath or to compensate for collective anxiety. One student writes:

> Fear of the wolf is archaic; it goes back to ancient times. … A realm of fantasy has developed around the wolf leaving little scope for rational analysis … Its negative image is largely inflated. It remains an animal that must unburden itself (sic!) of quite a reputation which it has dragged along since the old times. It should not be subjected to a rash "witch-hunt". For, even if religious obscurantism is out of place today, its image remains voluntarily associated with "evil".

Here, the students admit that the wolf is a scapegoat for the problems of pastoralism that have nothing to do with the animal.

The question of human safety is broached in a fundamentally different way: the wolf is afraid of man, so despite the *ancestral fear* of the wolf, it does not attack man; on the other hand, as we have seen above, the reintroduced Slovenian bear is not afraid of man, does not run away from him and can attack. In addition, for them, the reintroduction of the bear has required unacceptably high levels of financial investment, whereas the wolf came of his own accord, obviously without generating any need for financial investment. But, in fact the essential controversy here is connected to the one surrounding the bear. What if the

wolf had not returned naturally after 70 years of absence, what if it had been reintroduced? The students debated this issue often raised by shepherds in Mercantour. It is linked to the Berne Convention of 1979, which would correspond to the re-emergence of the wolf in Mercantour. This convention aims to ensure the conservation of the wildlife and the natural habitats of Europe by way of cooperation between states. In this convention, wildlife constitutes a natural heritage of great value that must be protected and transmitted to future generations. Skeptics believe that this simultaneity is not just a coincidence and that it covers up a voluntary reintroduction of the wolf. The students discuss, amongst themselves, the verification of the wolf's natural return by way of DNA tests, certifying the Italian origin of the wolf. The evidence is debatable: after all, there could have been a voluntary reintroduction of wolves of Italian origin.

Ultimately, the students' position on these two SAQs is different. Cohabitation is possible with the wolf but impossible with the bear, even though in both these cases, the shepherd's point of view dominates in the students' arguments. They refuse the straightforward transfer of the argument that breeders and wolves live together without difficulty in Italy. In fact, on the Italian side, sheep are reared for milk; the animals are milked and monitored on a daily basis, which is not the case on the French side where they are reared for meat. On both these SAQs, they criticize the media for developing ecological arguments at the expense of sociological and zootechnical arguments.

Comparison of reasoning on local or global SAQs

The students applied systemic reasoning to the three SAQs considered (wolf, bear, and global warming) and identify the risks. It is only on the issue of the reintroduction of the bear that they fail to evoke a single doubt. The students carry out a metacognitive analysis of global warming. They explain the evolution of their knowledge and shift in their questioning. They were not able to do this when working on the questions of the wolf and the bear because they were emotionally and culturally involved in the issues. Their points of view, on these local SAQs, were strengthened and not shaken by the teaching activities used. On the subject of global warming, they admitted that before working on it, they had all been convinced by the media that it existed, that its anthropogenic cause was linked mainly to CO_2 emissions, and that it was necessary to take political measures to reduce greenhouse gas emissions. They believed that the controversy was focused more on the type of actions to be taken and on the assessment of the scope of the phenomenon in the future.

> At the outset of my documentary research, my feeling was that ultimately the causes of global warming are well known and that the point of controversy lies solely in the actions to be taken concerning greenhouse gas emissions, that is to say the management and consumption of fossil fuels. When refining my work, I realized that there is not only a difference of opinion on the very notion of global warming itself and on the determination of its causes, but also on the assessment of the consequences.
>
> To my mind, the anthropogenic causes of global warming were obvious. Indeed, before this work, my standpoint was clearly defined by media influence and by what I'd read. It even seemed astonishing to me that these causes could be questioned. However, I became aware that valid theories were put forward. It is interesting to be able to challenge concepts and propose a set of assumptions to give everyone the possibility to think things over for themselves. Faced with the psychological weight

> of the question of anthropogenic global warming on all of us,it is reassuring to be able to get slightly in the way of the declared certainties. Having said this, there is no doubt in my mind that we need to take the necessary measures to avoid exacerbating the phenomenon.

Students discovered different levels of controversies: global warming versus climate change, anthropogenic causes versus natural causes (in particular those linked to solar activity), and the impact or non-impact of the reduction of CO_2 emissions. As noted in the introduction, one characteristic of SAQs lies in the difference of opinion amongst scientific experts, another resides in the fact that there are different categories of symbolic producers (associations, citizens, professionals). In the framework of global warming, some voices (minorities) are raised to denounce the "factory of scientific consensus" within the IPCC (International Panel on Climate Change) that aims to cover up clashing interpretations (Albe 2007).

Whereas for some, the decreasing volumes of ice in the Polar Regions are proof of the accelerated global warming in progress (and satellite pictures back this up), for others, the different observations made in the Arctic and in the Antarctic seem to indicate a different climatic modification in the two hemispheres. A certain number of climatologists question the modelizations offered by IPCC experts and would like other hypotheses to be envisaged by considering for example, alongside CO_2 emissions, the impact of water vapor, which is the main greenhouse gas (representing 60% of the atmospheric greenhouse effect).

In France, within the framework of the "Grenelle" (open debate) on the environment in October 2007, observers regretted that the issue of global warming took up so much more of the debate than other issues, particularly the issue of GMOs. One analysis used to justify the emphasis placed on this question was the force of scientific consensus characterized by a unified voice on the matter, the IPCC, and a unit of action, the rate of CO_2, as opposed to the polyphony of analyses on the impact of GMOs, on biodiversity, or on how to measure the latter. But, for other scientists, the conclusions of the IPCC are too toned down. The students succeed in identifying the controversies underlying the widely mediatized consensus on global warming.

Not only do students apply systemic reasoning to global warming, they have also become aware of the difficulty in analyzing the climate scientifically because of the important role played by the chaos theory in this domain. If one student explains where the origins of the confusions may lie: "There is a risk of confusing the different terms used on the subject. We easily mix up global warming and climate change, the natural phenomenon of the greenhouse effect and greenhouse gas emissions." Another student reveals his misconception: "Greenhouse gases damage the ozone layer, it's the hole in the ozone layer that causes an increase in the temperature of the globe." It is when considering the SAQ of global warming that they display the greatest number of uncertainties. "Determining whether the modifications are solely due to human activity is a very doubtful task." "On the other hand, one thing is certain, climatology is a complex science, where it is difficult to predict the future; the quantity of factors contributing to the climate, render the predictions invalid." "The complexity of climate science. Numerous factors participate in the change in temperatures (solar radiation, water vapor) and make it difficult to draw precise conclusions."

When analyzing the results of the IPCC, this same student remarks that the IPCC puts scientific uncertainty into perspective: "If there is any doubt within the IPCC, it concerns the change in the global economy, which can introduce margins of error. However, for

them, the scientific uncertainty related to the complexity of the issue is less important. The students also identify the need for further research:

> People like Claude Allègre [education minister 1997–2000] accord a certain questioning of the reality of the subject which appears to be a fatality. Indeed, perhaps our knowledge of the subject is still too restricted and we must try and gain a better understanding in order to anticipate and react more effectively to the possible changes. It is also a case of being less narrow-minded and challenging the elements we thought were established facts.

Overall, four aspects can be distinguished in the students' reasoning on the local SAQs (bear and wolf) and the global SAQ (global warming): (a) the mode of governance and the impact of politics, (b) the evaluation of expertise, (c) the consideration of the different actors and contexts, and (d) the degree of identification with certain categories of actors. Despite the famous sustainable development slogan "act locally, think globally", the students did not consider in the same way the question of the mode of governance and political discernment concerning these local and global SAQs. In the case of local SAQs, the students denounced the absence of consultation on a local level; it is the "act locally, consultation on the local level" that matters. In the case of global warming, it is the "think globally" that dominates; the "act locally" is not developed. The students call for a worldwide strategy, but ultimately, in their discourse, worldwide only concerns western countries. The Kyoto Protocol is at the heart of political argument.

Thus, they do not support the discourse of Stott and Sullivan (2000) for whom global warming is a myth invented in 1988 to replace the old fears surrounding the confrontation of the two super powers and it is in line with the 1972 Club of Rome and other neo-Malthusian fears. One student writes: "For sure, these authors actually attack the Kyoto Protocol, insinuating that it diverts our attention from what is human nature: adaptability. But isn't the protocol just a political means to make us change our habits in order to be better adapted to natural constraints?" The students link politics and economics:

> It is precisely at this point that the purely scientific issue takes on a political aspect. Indeed, global warming, if it is caused by man, obviously calls his activities into question. Notably, some very lucrative activities such as oil production, the car industry … are the first to be singled out as shameful. The faked reports issued by oil companies on global warming, the non-ratification of the Kyoto Protocol by countries who organize wars over oil production are all facts that may reveal to us the stakes involved in justifying a certain skepticism towards global warming.

The students also demonstrate skepticism towards the information available. In the cases of the bear and the wolf, they challenged the validity of the expertise and not the integrity of the experts; in the case of global warming, they try hard to understand the differing arguments of experts from the scientific world. But they also consider dishonest manipulation of the expertise, due to the financial interests. "False studies are financed to confirm the population's belief in a strictly natural phenomenon … the oil group Exxon-Mobil's methods of disinformation. Similarly the Bush Administration in 2005, allegedly censured research carried out by NASA."

Clearly, in the case of the wolf and the bear, the students favor the opinions of the shepherds and the context of pastoralism. In the case of global warming, a consideration of the different actors and contexts is not developed. They think "globally". They do not become emotionally involved, nor do they identify with the particular actors. They focus on "future generations". Only one of them, while broaching the issues of bio-fuel

production, the increase in biomass through photosynthesis thanks to an increase in the rate of CO_2, the impact of drought on crops and parasites, relates the question to the farming world and even to the Common Agricultural Policy. Apart from the analysis of scientific controversies and therefore the mention of the scientists' opinions, they only take into account superficially the oil companies' interests (Table 1).

Analysis of the analytical grids for socio-scientific reasoning

At the end of this training course, the students proposed some analytical grids for SAQs. They were designed in different ways. One is based on setting up a debate, another one on systemic simplification; the others were elaborated on the basis of a series of operations to be carried out. Here are some examples of the grids that are significant to these latter propositions.

Grid 1:

- Immersion into the environment essential to begin with (as it was specified orally 'to achieve objectivity')
- Consideration of all the possible arguments
- Reassure oneself of the pertinence of the arguments evoked
- Understand the stakes for each type of actor
- Consider the media, political and societal stakes

Grid 2:

- Define the framework of the issue, the different stakes (scientific, economic, social, etc.), the different actors concerned
- Analyze the points of view of the actors concerned, in the media
- In which context?
- Analyze the arguments
- Go back over the line of argument after being immersed in the different arguments

Grid 3:

- Research for documents relating to the issue in hand
- Study of the context and of the controversy
- Sorting the articles according to the points of view expressed
- Study of the articles (as it was specified orally 'in the most neutral way possible')
- Selection of the most pertinent articles
- Consideration of the different points of view in order to take a stand.

In these grids, we find the key elements to consider for the students: the context, the stakes, the media, the points of view of the different actors, the pertinence rather than the validity. We think it is interesting to comment in particular on the following grid, designed by two students:

- Analysis of the ambiguity of data open to interpretation by the different parties
- Analysis of the personal involvement of the actors concerned by the debate, which often makes it difficult to consider the situation objectively and exchange ideas
- The need to multiply the different sources to perfect our critical thinking
- Debate too often carried on by experts leaving little room for discussions with ordinary citizens

Table 1 Comparison of the socio-scientific reasoning concerning the three SAQs considered

SAQ	Bears	Wolves	Global warming
Spatial scale	Local	Local	Global
Systemic approach of SD	++	++	++
Examining the issue from different perspectives	+++ But by over expression of affect and identification with the shepherds	+++ But by over expression of affect and identification with the shepherds	+ Mainly that of the scientific experts
Need for more research	−	+	+++
Scepticism	+	+	++
Identification of risks	++	++	++
Identification of uncertainty	−	+	+++
Consideration of the values	+++	+++	+
	Affect breeder/animal reared	Affect breeder/animal reared	Solidarity between generations
	Psychological price (job loss)	Psychological price (job loss)	
Type of governance and place given to politics	+++	+++	+
	Demand for a participative form of governance	Demand for a participative form of governance	Respect of the Kyoto Protocol
	Criticism of the "top down" policy of the CAP.	Criticism of the "top down" policy of the CAP.	

Note: The operations in italics correspond to socio-scientific reasoning as defined by Sadler et al. (2006)

The awareness of the specific nature of SAQs is formalized by way of this last analytical grid. Beyond the fact that experts using different theoretical frameworks can interpret data differently, they expose the potential for misleading interpretation or at least one that is biased by the protagonists' interests or convictions. It is the social and argumentative use of the data that is challenged, more so than its epistemic value. These students recognize the importance of the personal involvement of the actors; this identification is the first step towards making a detached analysis of the discourses. And finally they put their finger on the need for a peer extended community of post normal science to allow discussion with ordinary citizens. The socio-scientific questions debated from a sustainable development perspective come into the domain of post normal science defined by Funtowicz and Ravetz (1993) as a science with important links to human needs, a bearer of huge uncertainties, high stakes, and values, requiring urgent decision-making. The social dimension of the sciences is emphasized in post-normal science. These authors do not defend an absolute form of relativism, but insist on the fact that the processes of decision-making in post normal science must include open dialogs with all concerned parties. They introduce the notion of "peer extended community". It is advisable for them to weigh up the societal consequences of the alternatives.

Conclusion

During this training course conceived from the education for sustainable development perspective, we observed that the students' social representations of bears and the socio-scientific reasoning of the students was far more strongly influenced by their meetings with stakeholders in this real life situation than by the study of articles showing environmental, economic and social arguments for both sides of the case. It was only possible to analyze the way the students justify their positions by taking into account the full context of the training course and the socio-cultural backgrounds of the students. A real-life situation reinforced the way the students got involved in the question, but at the same time, led to them taking an exaggeratedly emotional position. Teaching a SAQ from an education for sustainable development perspective requires an interdisciplinary approach based at least on the three considerations required for sustainable development: the environment, society, and economics. But, as we have seen, it was necessary here to complement these parameters by adding ethical and political dimensions. We extended the socio-scientific reasoning model suggested by Sadler et al. (2006) based on four desirable operations (recognizing the inherent complexity of the issue studied, examining the issue from multiple perspectives, appreciating that the issue is subject to ongoing inquiry and exhibiting skepticism when presented potentially biased information) by adding two operations: identifying the risks and uncertainties and taking into account the values (values possibly influenced by the culture, the society, or the media) or ethical principles underlying the way decisions are taken. We observed that the students did not perform two operations: they did not perceive that the question required further research and they did not identify uncertainties. By accepting the established position of the anti-bear shepherds (examining the issue from multiple perspectives and exhibiting skepticism when presented potentially biased information), two operations were performed only partially.

Globally, the students' pattern of reasoning on the issues of the bear and the wolf is similar, with the exception of two operations that are not brought into play concerning the wolf: the need for further research and the identification of uncertainties. If we compare the reasoning on these two local SAQs to the reasoning developed on the question of global

warming, the essential differences concern the place held by the emotional dimension and the importance of the desired participatory governance. The education for sustainable development viewpoint seems to require extending the socio-scientific reasoning to the political field; it is not only a matter of examining the question from different points of view but also of analyzing the social organization and the participation of stakeholders in the decision. It is necessary to analyze how well collective (or indeed institutional) decision-making meshes with individual decision-making and how well overall organization (national or global) meshes with local organization. Various social actors seek new modes of governance in which the consultation of the individuals concerned is fundamental to institutional decision-making. Here we find the notion of the peer extended community of post-normal science.

Depending on the issues dealt with, it is worth incorporating into the socio-scientific reasoning a consideration of the different scales: social (individual/collective while integrating the importance of politics), temporal (short/medium/long term), and spatial (local/regional/global), as Audigier suggests, within the framework of education for sustainable development. Consequently, we suggest completing this reasoning with four operations: (a) the identification of the risks and uncertainties; (b) the research and evaluation of the knowledge produced by non-academic producers of knowledge (professional groups, associations, consumers), Bourdieu's other symbolic producers; (c) the consideration of the values (potential values marked by cultural, societal or media elements) or ethical principles which influence opinions; and (d) the analysis of the modes of governance and the balance of power in the local or global orientations.

In this study, we observe that the greater the proximity between the question considered and the students—a local issue in which they are implicated because of their socio-cultural origins—the lower the level of scientific learning (critical analysis of their ideas, knowledge appropriation, socio-epistemological thinking about the knowledge involved, reasoning). The over expression of the affect wins over on the rest. But sometimes mobilizing the affect actually encourages the search for scientific counter arguments in order to refute the differing opinions. This was the case in the analysis carried out by Jimenez-Aleixandre (2006) of the scientific learning of Galician pupils confronted with the sinking of the *Prestige* and the resulting oil slick. In these apparently contradictory results, we find the imprinting of values on learning. If the situation presented to the students contradicts their system of values, the affect can hinder critical reasoning, blind them, and build resistance; if, however, it allows them to defend socio-cultural positions, it stimulates critical analysis.

How can we achieve the correct distance to foster motivation, the emergence of a need for scientific and social knowledge on which it is appropriate to apply a critical analysis, a detachment from the a priori? On the local question the one closest to the students, there was a rejection of the differing arguments presented in the texts. On the global question, we saw an often very fine analysis of the articles and the contradictory arguments and a detachment from prior conceptions.

Although contextualization is supposed to improve situated cognition and encourage scientific learning by giving a meaning to scientific knowledge, we have seen here the limits of a local contextualization that involves students too much. Nevertheless, the analysis of local or global socio-scientific questions from a sustainable viewpoint may foster the integrated mobilization of interdisciplinary concepts and encourage the scientific citizenship of the students. Education for sustainable development should allow the development of critical thought. In critical theory, the goals of efficiency or technological progress justifying all the means involved must not be given priority over democracy, and education plays a central role in social transformation. We can then refer to the

argumentation of Jimenez-Aleixandre and Erduran (in press). Jimenez-Aleixandre and Erduran—consistent with the position of Carr and Kemmis (1986)—oppose critical rationality and technical rationality; based on the latter, all problems have a technical solution and individuals do not have to apply their thinking to control the world. Thanks to the development of critical rationality, the issue in question for education for sustainable development has become one of empowerment which targets the capacity of the students to transform society. We link, then, scientific democratization, problematization, and action.

We believe that this research should be pursued in order to pin down the specific characteristics of socio-scientific reasoning from an education for sustainable development viewpoint and to study more deeply the relationship between the way situations are stated or problematized and actions.

Inspired by Tozzi (2001), Simonneaux (2006) has defined four didactic methods for analyzing teaching practices concerning sustainable development, each paradigm having a specific learning objective: (a) the historical method stresses teaching the way the concept first arose and evolved; (b) the doctrinal method considers how individuals adopt the principles of sustainable development; (c) the problematizing method focuses on identifying the various points of view; and (d) how they are defended while the praxeological method seeks to favor sustainable development behavior. This training situation is an illustration of the problematizing method. L. Simonneaux defines within this logic, four methods for teaching SAQs: (a) a genetic method based on the construction (by different producers of knowledge) of disputed knowledge on SAQs; (b) a doctrinal method based on the adherence to ethical, political or economic principles; (c) a problematizing method based on socio-scientific reasoning; and (d) a praxeological method seeking to foster attitudes, involvement in action.

The last two methods of these frameworks are not necessarily exclusive. For Fleury and Fabre (2003), the main thing when teaching problematization is to set in motion, not a search for data of a documentary type, but rather a search for the meaning of data involving argumentation activities. Teaching problematization calls for "thinking beyond" the praxeological standpoint. It is an approach that enables the identification of the possibilities of action. The training situation of the degree students analyzed here, was set up using the problematizing method. It therefore is clear that an authentic local issue entailing "too much" involvement can limit learning and critical thought, we may wonder whether this risk is not increased within the framework of a praxeological method. The first question is to determine what the educational system expects and sets as learning goals: appropriation of scientific or pluridisciplinary knowledge, construction of socio-scientific reasoning, construction of opinions or attitudes. The second is to define the teaching methods to be used and to evaluate (but only at this stage) their efficiency. Crossing the frameworks proposed by J. Simonneaux on education for sustainable development and L. Simonneaux on the teaching of SAQs, may enable us to analyze the teaching practices of a SAQ within the perspective of sustainable development.

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