Socioscientific Issues in Science Education: An opportunity to Incorporate Education about Risk and Risk Analysis?

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Socioscientific issues (SSI) concern social issues, often lacking simple solutions, that relate to science and often also risk controversies. SSIs have become an established part of science education, aiming to teach students not only about content knowledge but also about the nature of science and to offer them practice in argumentation and decision making. We performed a scoping review of the literature on SSI in science education research, in order to investigate if the topics covered would lean themselves to education about risk, and if risk is raised in these works. Using Web of Science we identified 296 empirical publications and 91 theoretical or review publications about SSI teaching in science education. The empirical publications covered studies performed in primary to tertiary school, most commonly upper secondary school (32%). The most frequently taught SSI themes were nature conservation, biotechnology, and climate change. Despite that these, as most of the other identified themes, clearly are connected to risk analysis and risk management, few publications raised the concept of risk and the methods of risk analysis. In fact, almost half (empirical: 48%, theoretical: 49%) did not mention risk at all. We argue that SSIs present an opportunity for risk researchers to engage with educators to incorporate risk in school science education and to contribute in developing teaching materials suitable toward that aim.

1. INTRODUCTION

Risk is a concept of high significance for us as citizens. Daily, we make multiple risk decisions, to avoid risks or to take a risk in order to gain benefits. While some of our daily risk decisions are straightforward, some are very complex and would benefit from knowledge about the concept of risk and how risks are assessed and managed. This knowledge, and the skillset to apply it to structure a decision-making process, is thus relevant to all members of society and consequently as a topic in primary and secondary school (K-12 education). This has also been discussed within the risk research community. Briscoe (1992), called the “almost total lack of risk teaching in high school consumer education classes” (combined with a lack of national risk standards), “a serious indictment of the government and scientific and educational communities” and suggested that public education should include the risk concept, utility theory, and risk perception factors. The Society of Risk
Analysis’ (2018a) has published a list of core subjects of risk analysis serving as a resource for educators at varying levels as “[t]here is a spectrum of needs, ranging from high school level (and even below) to graduates and professionals in the field” (SRA, 2018a). The core subjects are sorted into five overarching categories:

1. Fundamentals; the basic concepts and principles in risk analysis.
2. Risk assessment; principles, approaches, and methods for identifying, qualifying, and/or quantifying risk.
3. Risk perception and communication; including the influence of affect and trust, exchange and sharing of risk-related data.
4. Risk management and governance; strategies and processes, tools, and principles for situations of variable degree of complexity.
5. Solving real risk problems and issues; an integration of the previous four core subjects into real practice.

The level of depth into which a teaching segment will go in each of these categories needs to be adapted to the target group and level of education (SRA, 2018a). More specifically targeting K-12 education, Aven and Michiels van Kessenich (2020) identified four scientific pillars of understanding risk and risk management:

1. The basic concepts (risk, uncertainty, probability) and the relationships between them.
2. The difference between professional risk and uncertainty assessment and risk perception.
3. The balance taking risk and reducing risk in risk management.
4. The need to distinguish between individuals, organizations and society.

Risk has been raised as a “central idea about science” in the context of science education (Millar, 2006). Risk, risk assessment, or risk analysis are dealt with in a variety of ways within science education research (Christensen, 2009; Cross, 1993; Hansen & Hammann, 2017; Schenk et al., 2019). This is particularly true for the areas of scientific literacy, Science and Technology in Society (STS), and socioscientific issues (SSI; Boerwinkel, Swierstra, & Warloo, 2014; Kolstø, 2006; Levinson, Kent, Pratt, Kapadia, & Yougi, 2011; Simonneaux, Panissal, & Brossais, 2013; Wojcik et al., 2019). The origins of this stream of research lies in the idea of making science education more socially responsible and contribute to science for citizenship and may be traced back at least to the 1930’s (Ratcliffe, 2001), although it began to be more widely argued from the 1970’s (see Howes, 1975). The STS movement aimed to include controversial issues in which both scientific and social aspects need to be considered in education (see for instance Gaskell, 1982). The first large-scale STS-project launched in the Netherlands in the 1970’s and concerned the debate on nuclear power (Eijkelhof, 1986). By the 1980’s, the term socioscientific issues was established (Fleming, 1986), and in a seminal 2005 publication, Zeidler and colleagues argued that unlike the STS-movement, SSI teaching and research constituted a coherent framework taking not only the cognitive but also the moral and epistemological growth of the students into consideration (Zeidler, Sadler, Simmons, & Howes, 2005). SSI has, since then, gained increased usage within science education research (Tekin, Aslan, & Yilmaz, 2016) and has grown into a major component of science education.

SSIs concern social issues that relate to science. They are also often controversial issues that lack a simple, or single, resolution. These are also characteristics of risk centered controversies and debates, making many risk issues potential SSIs (Christensen, 2009; Ratcliffe & Grace, 2003; Schenk et al., 2019). Teachers use SSIs for several reasons. SSIs may put the science in an every-day context for the students, showing the impact science has on our society and daily lives. The uncertain and sometimes missing knowledge connected to SSIs presents opportunities for teaching about the nature of scientific knowledge and the nature of science as practice (Kolstø, 2001a; Sadler, 2004). Additionally, teaching about SSIs offers students experience in applying scientific and moral reasoning to socially relevant topics (Grace & Ratcliffe, 2002; Sadler & Zeidler, 2004; Sadler & Donnelly, 2006). A common focus of published SSI research is students’ argumentation, decision making, and informal reasoning (Albe & Gombert, 2012; Sadler & Zeidler, 2005a, 2005b; Tekin et al., 2016). At first sight there are thus many points connecting the aims of teaching SSI with an understanding of the risk concept and risk analysis, including risk assessment and risk management decisions.

Our starting point is that SSI teaching may present a venue for introducing formal teaching about risk in K-12 education. In order to explore this opportunity, we have performed a scoping review of the SSI literature to investigate whether the topics covered in SSI teaching would lean themselves to
to evaluate the use of SSIs in teaching. We searched the Web of Science Core Collection using the search terms “socioscientific issue” OR “socio-scientific issue” refined by “science education” or a related acronym. Search terms were applied to title, abstract, keywords, and Keywords Plus (i.e., “Topic”). The search yielded 422 hits in April 2020. We believe this to be a comprehensive finding as the same search yielded 180 peer-reviewed studies in the specialized database Education Resources Information Center (ERIC). All bibliometric information and the abstracts were exported for further evaluation. After reading all abstracts, 29 records were excluded due to not concerning socioscientific issues (e.g., tasks centered around certain or uncontroversial knowledge such as water’s boiling point), three due to being book reviews and three due to being editorials. The remaining 387 records were downloaded if possible and sorted into one of two categories: empirical studies or theoretical papers/reviews. If we could not access/read full publications (n = 44, including language restrictions), as much information as possible was extracted from the English abstract.

For empirical studies, we identified the study population, topic of the SSI and occurrences of the word risk* (excluding list of references, appendices, and instances of risk being used to describe SSI teaching as a risk that teachers take or “at-risk” students). As a proxy for situations where knowledge about risk and risk analysis could be relevant, regardless of whether the risk concept was explicitly raised or not, we additionally coded the studies according to three topics. Namely, if the study, according to its abstract, investigated argumentation, decision making, or ethical/moral reasoning (connects to the role of values in risk, cf. Schenk et al., 2019). We categorized the student study populations according to the International Standard Classification of Education (ISCED) levels: early childhood education, primary education, lower secondary education, upper secondary education, and tertiary education. Primarily we followed the authors’ own classification, but if this was not according to ISCED we recoded the studies according to information about educational level (e.g., grade 10–12, high school, and form 4 were sorted as upper secondary school) or age (primary: 7–12, lower secondary: 13–15, upper secondary 16–18 years). Some studies covered both lower and upper secondary school students, these we categorized according to the majority group. If no information was available to differentiate the two (n = 4), we categorized the study population as upper secondary. For the theoretical/review publications we only investigated the occurrences of the word risk* in the main body of text (as also described above).

3. RESULTS

The final database included 296 empirical publications and 91 reviews or theoretical publications, with abstracts in English. The earliest publication was from 1994, and as seen in Fig. 1 the number of publications on SSIs in science education started to increase in the beginning of the 2000’s, as did the citation rate (Fig. 1). For 267 of the empirical publications and 76 of the theoretical/review publications, English full-length publications were available.

The overview of the empirical publications in Table I shows that science education research on SSIs focuses on K-12 education, and the education of teachers for these levels, as relatively few publications focus on tertiary education or public outreach activities.

The empirical publications cover a range of topics used as SSIs (Table I, see also Appendix Table A1), yet certain themes are frequently recurring. Questions on nature conservation (biodiversity, pollution, etc.) are treated in one-fourth of the
Fig 1. A bibliometric overview of the published research on socioscientific issues (SSI) in science education. Data compiled from Web of Science April 2020, numbers for 2020 excluded.

### Table I. Overview of Topics of Socioscientific Issues (SSI) Used and Groups Studied in the 296 Reviewed Empirical Publications.

Explanation of Categories is given in the Appendix

| Study population          | Primary school | Lower second | Upper second | Tert. | Public | Preservice teachers | Teachers | Textbook/curriculum | Sum   |
|---------------------------|----------------|--------------|--------------|-------|--------|---------------------|----------|--------------------|-------|
| SSI-topic                 |                |              |              |       |        |                     |          |                    |       |
| Nature conservation       | 10             | 19           | 24           | 9     | 2      | 7                   | 3        | 4                  | 78    |
| Biotechnology             | 1              | 11           | 26           | 9     | 0      | 8                   | 7        | 2                  | 64    |
| Climate                   | 1              | 9            | 15           | 3     | 1      | 9                   | 4        | 2                  | 44    |
| Nuclear/radiation         | 0              | 4            | 5            | 3     | 1      | 6                   | 0        | 1                  | 20    |
| Chemicals and human health| 0              | 4            | 5            | 3     | 1      | 5                   | 3        | 1                  | 20    |
| Alternative energy        | 2              | 1            | 2            | 1     | 2      | 2                   | 0        | 0                  | 10    |
| Consumer choices (LCA)    | 0              | 4            | 3            | 3     | 0      | 0                   | 0        | 0                  | 10    |
| General                   | 3              | 7            | 6            | 3     | 0      | 12                  | 21       | 3                  | 55    |
| Focus                     |                |              |              |       |        |                     |          |                    |       |
| Argumentation             | 7              | 11           | 36           | 16    | 2      | 19                  | 5        | 1                  | 97    |
| Decision-making           | 2              | 11           | 30           | 9     | 0      | 6                   | 5        | 2                  | 65    |
| Ethics/moral              | 4              | 6            | 18           | 6     | 0      | 6                   | 7        | 4                  | 51    |
| Sum of publications       | 17             | 48           | 95           | 37    | 5      | 42                  | 40       | 12                 |       |

LCA = Life cycle analysis; Tert. = Tertiary education; second = secondary school

*a* Several studies use more than one SSI, hence numbers in this column are larger than the number of publications reviewed.

*b* This row only includes each publication once.

*c* General means publications focusing on SSIs as a topic rather than employing any particular SSIs in the education. For instance, investigations of what the study population characterizes as an SSI or perceived opportunities and obstacles with SSI teaching.

publications (26%), making it the most common type of SSI. Almost as many studies employed an SSI connecting to biotechnology, including genetic engineering (22%). While nature conservation was the most common in all K-12 education, biotechnology was mainly employed in upper secondary school teaching and is also the most common of the SSIs targeting preservice and in-service teachers. Climate change prevention and adaptation was the third most common category, employed in 15% of the empirical publications. The category “general” in Table I is the most frequently encountered for works targeting pre- or in-service teachers, this category does not denote any specific SSIs being employed, but rather that the
topic for the empirical investigation was focused on SSIs as a tool for teaching. Overall, all categories concerning employed SSIs have a component of risk, such as the potential for harm to human health or the environment, human rights, or other aspects that humans may value (e.g., integrity issues connected to genetic testing).

Moving on to the purpose of teaching with SSIs, 97 (33%) publications had a focus on students’ argumentation and 65 (22%) on decision making. The overlap between these two was 20 publications. Another interesting aspect is that 51 (17%) publications emphasized the need to include moral and/or ethical reflection in science education (Table I).

We searched the 343 full-length publications for the word risk*, including risky, risking, but excluding words such as asterisk or risk* describing that teachers take a risk when implementing SSIs. While a simple measure, it illustrates how few publications explicitly engage with the risk concept (Fig. 2). Half of the publications do not even mention risk, and another 37% mention it less than a handful of times. Less than 3% of the empirical publications (n = 7) engage more extensively with risk, naming the concept more than 30 times. One of these is also the only empirical publication in our database using the word risk in the title (Christensen, 2009; Hansen & Hammann, 2017; Wojcik et al., 2019). Three of the publications also use the word risk in the title (Christensen, 2009; Hansen & Hammann, 2017; Wojcik et al., 2019).

Table II presents the seven empirical publications most engaged with risk. Compared to the time frame for the whole database (Fig. 1) these risk-frequent publications are among the more recently published (see also Appendix Figs. A1 and A2). Five of the seven publications do not give any definition of how they interpret risk and only one of the seven explicitly mentions that risk is a concept that can be defined (or operationalized) in many ways. The tension, or gap, between technical risk descriptions (experts’ risk assessments) and lay persons’ risk perception is raised by three of the seven publications, two of which are focused on genetically modified organisms (GMO) as an SSI. The low number of publications and variability in SSI topics do not allow any connections to be made between topic and approach to the risk concept in the empirical studies.

4. DISCUSSION

The overview of the literature on SSI in science education has shown that SSI teaching is a growing field and that the topics covered as SSIs in most cases concern issues of risk (Table I). However, studies on SSI teaching generally do not delve into the understanding of risk, or the role of this in students’ decision making. The published research on SSI teaching does not define the authors’ take on risk, even if reporting on a risk related SSI. Hence, there could be a better foundation in the basis of risk analysis.

One aspect of scientific literacy and educated citizenship relating to risk is the ability to make informed decisions. When we set students to discuss and motivate their decisions, the interaction between scientific knowledge and values is difficult, and there is a tendency to lean only on one or the other (Albe, 2008; Nielsen, 2012; Sadler & Zeidler, 2005b). The tools of risk analysis can help in map out the complexity of SSIs drawing on risk issues, and hence structure argumentation and inform decision making. While SSI teaching will not be a venue to educate fully fledged risk analysts, there are mutual points of interest between risk analysis education and SSI teaching.

When teaching with SSIs, students are often given a task of solving a real risk problem, or at least form an informed opinion of the issue at hand. Many studies point to an ambition of training students in ethical/moral deliberations (Table I), which connects
Table II. An Overview of the Seven Empirical Publications that Mention Risk* At Least 30 Times

| Authors                      | Study Population             | SSI Topic                      | Risk Definition                                                                 |
|------------------------------|------------------------------|--------------------------------|---------------------------------------------------------------------------------|
| Kolstø, 2001b                | Upper secondary students     | Electromagnetic radiation      | No definition of risk given.                                                     |
| Simonneaux et al., 2013      | Upper secondary students     | Nanotechnology                 | Describes experts “measure of risk as ‘risk (consequence/unit time) = probability (events/unit time) × consequences (consequences/event),’ which is stated to be less complex than lay persons’ assessment of risk (risk perception or social representation of risk).” |
| Ozturk & Yilmaz-Tuzun, 2017  | Teachers                     | Nuclear power                  | Acknowledges that many definitions exist, presents “usually it refers to the probability that an individual faces danger” |
| Cinici, 2016                 | Preservice teachers          | GMO                             | No definition of risk given. Focuses on risk perception rather than risk analysis; acknowledging that “there is a distinction between experts' scientifically assessed risk and perceived risk in the eye of the public” |
| Bay, Vickers, Mora, Sloboda, & Morton, 2017 | Lower secondary students | Noncommunicable diseases (NCD) | No definition of risk is given, yet targets education about NCD risk, and also categorizes participants into “at risk” or “no-low risk.” |
| Genel & Topcu, 2016          | Preservice teachers          | Several, for example nuclear power and pest control. | No definition of risk is given, but a good risk analysis is stated to include “risk statistics or probability” and explanations of “the interactions between possible risks and values.” |
| Maes, Bourgonjon, Gheysen, & Valcke, 2018 | Lower and upper secondary students | Food crop GMOs | No definition of risk given. Focuses on risk perception rather than risk analysis, pointing to the difference between expert judgement on, and lay persons’ perception of the safety of GMO foods. |

to the SRA (2018a) risk analysis core content on how to balance outcomes of different decision alternatives in risk management. As seen in Table II, some of the empirical SSI studies take the difference between professional risk assessment and risk perception as a starting point for motivating their teaching and research. Both SRA (2018a) and Aven and Michiels van Kessenich (2020) point out the importance of a foundation in the basic concepts but based on our review this knowledge content is seldom included in SSI studies.

From the science education field, Hansen and Hammann (2017) also touch on these foundations. They identified three core components of teaching about risk, building on each other in the development of students’ risk competency. The first pillar is scientific knowledge and statistics/probability, including knowledge about the risk issue, basic understanding of statistics and experts’ risk judgements as well as reliability of data. The second pillar is knowledge about science, for example, uncertainty, science in society and science as social practice. The third pillar is risk assessment, including risk-(cost)-benefit analysis, ethical deliberations, and decision making. These pillars cut the aspects of risk analysis a bit differently than SRA (2018a) or Aven and Michiels van Kessenich (2020), but largely there is an overlap in the desired content knowledge on risk analysis between the three works.

Having established that there are mutual points of interest in what to teach, we wish to turn to the issue of who or when (age) to teach about risk analysis connected to SSI. Aven and Michiels van Kessenich (2020) pointed to a need to teach students “of a sufficiently early age” about risk; the article also reports from experiences of a teaching sequence implemented in primary school. As also previously found by Tekin et al. (2016), empirical studies on SSIs in science education (Table I) most commonly target upper secondary school, followed by lower
secondary. The complexity of SSIs and the content knowledge they draw on in many cases (e.g., radiation physics, genetics) make them more suitable for the secondary school level. In relation to tertiary education, it should be noted that at this level there are courses and also full programs that target risk analysis, or its subcomponents, and as our review was focused on SSIs in science education, it did not cover such specialized education.

A substantial part of the empirical publications we reviewed focused on pre- or in-service teachers (Table I), investigating their understanding of SSIs, practice of SSI teaching and knowledge needs. It should be acknowledged that teaching about risk and SSIs pose many challenges to science teachers. A general theme in the literature on teachers’ hesitation to teach SSIs concerns the lack of appropriate teaching materials as well as other resources such as time (Hancock, Friedrichsen, Kinslow, & Sadler, 2019; Leden, Hansson, & Redfors, 2017; Lumpe, Haney, & Czerniak, 1998; Nida, Rahayu, & Elks, 2020; Pedretti, Bencze, Hewitt, Romkey, & Jivraj, 2008) or support from colleagues (Pedretti et al., 2008). Another important constraint concerns the requirement (perceived or actual) to meet standards in state curricula (Nida et al., 2020; Pedretti et al., 2008; Sadler, Amirshokoohi, Kazempour, & Allspaw, 2006). Finally, teachers often refer to lack of knowledge of, or confidence in, managing or scaffolding class discussions on controversial issues (Bryce & Gray, 2004; Lee & Yang, 2019) or a preference for focusing on the science content and avoiding values (Lee & Witz, 2009; Lundqvist & Lund, 2018), which indeed often incur difficulties for students when needing to be balanced with facts and content knowledge (Albe, 2008; Grace & Ratcliffe, 2002; Lindahl, 2009; Sadler & Donnelly, 2006; Sadler & Zeidler, 2005b). Opening for classroom discussions on values, teachers may worry about imposing political views on their students (Jickling, 1992; Pedretti et al., 2008), be unwilling to express their own values in the classroom (Cross & Price, 1996; Oulton, Day, Dillon, & Grace, 2004).

Parts of these challenges need to be addressed within the education community and/or in the sociopolitical context of the educational system, such as the curriculum and working conditions. But other parts highlight that teaching about SSI and about (aspects of) risk analysis requires that teachers are given the tools and knowledge to do this. We argue that the risk research community and the Society of Risk Analysis may offer valuable contributions to this. Teachers may be discouraged from risk assessment due to perceiving it as too complex, or too mathematical. Yet, there are many ways to express risk, some more complex and some more intuitively available, such as a risk matrix, but this knowledge is not easily available for K-12 teachers. Teaching materials on how to describe and explain the basic concepts and principles on risk analysis will be needed to meet the needs of science educators, as will material on suitable case studies with authentic questions on risk assessment, management, and communication. For K-12 education an additional challenge will be to determine a suitable level of depth and complexity. While simplification will be needed it should be balanced with authenticity to avoid overly simplistic materials. Materials such as the core subjects of risk analysis (SRA, 2018a) and the glossary of risk analysis (SRA, 2018b) are valuable toward this. However, to develop high quality teaching materials we believe that collaborations between experts on risk analysis, or a particular risk issue with science education researchers and teachers will be necessary. Such collaborations across disciplines and professions can make valuable contributions to teaching the future educated citizens and decisionmakers (see also Wojcik et al., 2019).

One example of output from such a collaboration from our own research is a tentative model of the risk concept for science education (Schenk et al., 2019). The aim of the model is to aid teachers to understand the nuances of the risk concept and as a didactic tool for planning or evaluating teaching sessions involving risk issues (e.g., an SSI decision-making assignment). The model is based on a review of the literature on risk in combination with an iterative process of discussion within the framework of two collaborative research projects between risk assessors, science education researchers, and science teachers. There are a few examples also describing the process of collaboration in developing SSI teaching. Signer and Stapert (2020) describe the process from idea to implementation of a curriculum on climate change, that was developed in collaboration between a private school, a climate education nonprofit, and the National Oceanic and Atmospheric Administration (NOAA). Another example is a teaching module on nanoscience and nanotechnology developed in a collaboration between in-service teachers, science education researchers, nanoscience researchers, and experts from science museums (Sgouros & Stavrour, 2019). The value of this collaboration and how it resulted in innovative teaching
materials is highlighted in the description of how the collaboration enriched teachers’ content knowledge and how teachers in turn clarified SSI’s regarding the nano science/technology applications.

5. CONCLUSIONS

We conclude that risk is a natural part of socio-scientific issues in science education, yet rarely acknowledged as content knowledge in its own right. Our extensive literature review showed that few of the publications investigated engage with the concept of risk and the methods of risk analysis, despite the fact that the SSIs taught in the investigated empirical studies more often than not connect to risk decisions. Thus, there is a significant and striking discrepancy between potential and realized opportunities to include risk and risk analysis in SSIs. Our results show that SSIs would be a suitable venue to incorporate more formal content on risk, given the nature of the topics generally covered. They also show that knowledge about risk analysis is valuable to SSI teaching, as it often is aimed at teaching students about argumentation reasoning and decision making; skills which risk analysis may contribute to. We argue, therefore, that risk should be a more central part of SSI teaching. To achieve this, however, teachers need support, for instance through didactic models and tools for how to teach about basic concepts in, and practice of, risk analysis. We thus see an opportunity for risk researchers to engage with the science education community and/or directly with science teachers to develop SSI-teaching. Risk researchers may contribute with knowledge and structure about risk as a concept and risk analysis practice, but also with case-specific knowledge about risk issues that can serve as SSIs, potentially broadening the range of issues used as SSIs in science education. We believe such efforts to be of particular relevance in times of pressing global challenges to ecosystems, human health, and society at large.

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## APPENDIX

### Table A1. Description of the SSI-Topics used for Categorizing the Empirical Publications

| SSI-topic                      | Description                                                                                                                                 |
|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| Nature conservation           | Biodiversity, pollution with a focus on environmental effects, groundwater.                                                                    |
| Biotechnology                 | Genetic engineering, genetic testing, cloning.                                                                                               |
| Climate                       | Climate change adaptation, climate change prevention.                                                                                         |
| Nuclear/radiation             | Nuclear power, ionizing radiation risk.                                                                                                       |
| Chemicals and human health    | Chemicals in products, nanomaterials, air pollution (focus on human health).                                                                   |
| Alternative energy            | Evaluation of alternative energy sources, no specific mention of climate change.                                                               |
| Consumer choices (LCA)        | Students were given a consumer choice in which various aspects were open for consideration (e.g., functionality, economy, environmental chemical pollution, greenhouse gases, health). |
| Sexual health                 | Sexually transmitted diseases, sexual health.                                                                                                 |
| Electro-magnetic              | Electro-magnetic / nonionizing radiation, mobile phones, overhead power lines.                                                                |
| General                       | Focuses on SSIs as a topic rather than employing any particular SSIs in the education. For instance, investigations of what the study population characterizes as an SSI or perceived opportunities and obstacles with SSI teaching. |
| Other                         | Other issues, for example animal rights, that occurred less than 5 times each in the material. Covers ~20 issues.                               |

### Fig A1. Number of times risk* is found in the main text of the empirical publications plotted over the year of publication, up until April 2020.
Fig A2. Number of times risk* is found in the main text of the theoretical/review publications plotted over the year of publication, up until April 2020. Note differences in x-axis scale.