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Taking Advantage of the "Big Mo"—Momentum in Everyday English and Swedish and in Physics Teaching

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Abstract Science education research suggests that our everyday intuitions of motion and interaction of physical objects fit well with how physicists use the term "momentum". Corpus linguistics provides an easily accessible approach to study language in different domains, including everyday language. Analysis of language samples from English text corpora reveals a trend of increasing metaphorical use of "momentum" in non-science domains, and through conceptual metaphor analysis, we show that the use of the word in everyday language, as opposed to for instance "force", is largely adequate from a physics point of view. In addition, "momentum" has recently been borrowed into Swedish as a metaphor in domains such as sports, politics and finance, with meanings similar to those in physics. As an implication for educational practice, we find support for the suggestion to introduce the term "momentum" to English-speaking pupils at an earlier age than what is typically done in the educational system today, thereby capitalising on their intuitions and experiences of everyday language. For Swedish-speaking pupils, and possibly also relevant to other languages, the parallel between "momentum" and the corresponding physics term in the students' mother tongue could be made explicit..

Keywords Momentum · Corpus linguistics · Conceptual metaphor · Semantics · Science education · Physics

Introduction

> CBS "Morning" interview with Bob Scheiffer:
> "What we'll have, you see, is momentum. We will have forward 'Big Mo' on our side, as they say in athletics."
> "'Big Mo'?" Schieffer asked.
> "Yeah," Bush replied, "'Mo,' momentum." (Greenfield 1982, pp. 39–40).

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For more than 30 years, it has been recognised within science education research that students often misinterpret Newtonian mechanics (e.g. Clement 1982; Hake 1998; McCloskey 1983b). One source of misunderstanding is that key physics terms, such as "force", have vague meanings in everyday language that differ from the more precise meanings in science (Williams 1999). For instance, in everyday language, an object in motion at constant velocity may be attributed a force in the direction of the motion, reminiscent of the pre-Newtonian notion of "impetus" (Clement 1982; McCloskey 1983b). Students may well have an adequate conception of the phenomenon, such as realising that an object will continue at constant velocity if all resistance is removed (Brookes and Etkina 2009). However, they tend to apply the term force in a way that does not align with Newtonian mechanics, where a force is not the kind of thing that an object might *have*, but something that is exerted on the object. As a result, university students have been found to fail basic conceptual tasks, such as drawing the forces acting on a coin after it has been tossed into the air. One student gave the typical explanation that as the coin moves up through the air, there is "a force going up" and that this "force of throw gets to be less and less because gravity is pulling down on it" (Clement 1982, p. 68), even though there is no such force. From a physics point of view, these are inadequate expressions involving force.

Osborne (1984) suggests that in learning mechanics, children are influenced by three clusters of dynamics reasoning: First, against the background of their embodied interactions with the physical world, the children have spontaneously developed their subjective *gut dynamics*, intuitions that help them make predictions and take appropriate action in everyday settings. Second, as a consequence of social interaction, the children are exposed to *lay dynamics*, reflected in the everyday language of people they meet, such as parents and teachers, or through media, such as books and TV. Third, at school, the aim of science teaching is for their pupils to adopt *physicists' dynamics*, largely corresponding to Newtonian mechanics. However, these three clusters of dynamics sometimes tell very different stories, which provide challenges for science teaching and learning. For instance, in imagining an object at uniform motion, our gut dynamics, which does not involve frictionless interaction, tells us that something would have to push the object forward. Similarly, in lay dynamics, we could say that the object has a lot of force. These experiences are difficult to coordinate with physicists' dynamics. Nevertheless, Osborne proposes that in science teaching, we should encourage pupils from a young age to make use of, but also challenge, their gut and lay dynamics in gradually appropriating physicists' dynamics. In this endeavour, "momentum" offers promising opportunities (Osborne 1984, p. 508):

> The concept of "momentum" is a central aspect of gut dynamics but it becomes incorrectly labeled as a force as a consequence of everyday language (lay dynamics). It can be argued that to develop gut and lay dynamics towards physicists' dynamics involves introducing the term momentum to children at a relatively young age, and later distinguishing it from force. Net force changes momentum.

Given such indications that "momentum" as a term might correspond well with our intuitive understanding of physical objects in motion, our gut dynamics, we were interested in finding out to what degree does written everyday language involving momentum, lay dynamics, fit with Newtonian mechanics. The development of text corpora offers electronic access to large databases of language samples. After an early focus on prestigious genres, such as fictional literature and newspapers, text corpora now provide increasingly representative samples of everyday language, e.g. blogs. Therefore, in the present research, we explore text corpus approaches to the analysis of metaphorical use of "momentum" in everyday language. In order to assess the adequacy from a physics point of view of the use of "momentum" in

identified sentences, tools from cognitive linguistics, such as conceptual metaphor analysis, are also applied. In particular, we first look at metaphorical use of momentum in English and then how the word quite recently has been borrowed into Swedish colloquial language, but not in physics where the Swedish translation of the physical quantity "momentum" is *rörelsemängd*, literally meaning *amount of movement*. From a pedagogical point of view, we discuss in what way physics teachers can take advantage of how momentum has come to be used in everyday language.

Momentum as a Physical Quantity and in Physics Teaching

"Momentum", or more specifically "linear momentum", is a physical quantity. As with many physical quantities, such as "mass" or "energy", it is difficult to provide a definition of momentum that is at the same time foundational and useful in pedagogical contexts. To our knowledge, the most foundational meaning of momentum relates to Noether's theorem that any differentiable action of a physical system has a corresponding conservation law. In particular, momentum is the conserved quantity that corresponds to invariance under translations in three-dimensional space. However, this kind of characterisation of momentum is largely unintelligible for students (and probably most teachers, including ourselves), so we need other ways to introduce the notion in teaching that are conceptually accessible.

In practice, in physics teaching, "momentum" is typically first encountered within Newtonian mechanics as $\boldsymbol{p}=m\boldsymbol{v}$, where m is the mass of an object and $\boldsymbol{v}$ its velocity. The bold font of momentum, $\boldsymbol{p}$, and velocity, $\boldsymbol{v}$, signifies that they are vectors, specifying an amount and a direction in three-dimensional space.[1] In this way, momentum may be conceptualised as something that objects in motion have or contain: the larger the mass and the velocity of an object, the larger its momentum. Now, momentum and exchange of momentum in interactions become very useful concepts in understanding mechanics and in practical problem solving. For instance, Brunt and Brunt (2013) show how momentum and the principle of conservation of momentum in an isolated system may be used to derive and conceptualise Newton's three laws of motion.

As we have seen, the medieval notion of impetus also referred to something that objects in motion have, and it is tempting to compare it to momentum. McCloskey (1983a) argues that the modern idea of momentum differs from impetus in that impetus was conceptualised as a cause of the motion and that objects in motion were seen as having impetus in an absolute sense, rather than in relation to a frame of reference. The impetus theory has been discarded and replaced by more useful theories, such as Newtonian mechanics, and students' reliance on impetus-like ideas should be regarded as misconceptions. In contrast, diSessa (1993) sees students' impetus-like intuitions as a productive resource when introducing momentum in science teaching. Students tend to intuitively embrace a kind of "generalised momentum", expressed as "Things generally continue to go as they have been going" (p. 225). The idea of momentum as contained in objects in motion may be taken one step further in imagining momentum as a conserved, substance-like entity that flows between objects as they interact by means of forces (diSessa 1980, 1993; Herrmann and Schmid 1985). diSessa (1980, p. 365) suggests that this approach is particularly useful for conceptualising Newton's third law, that a

[1] Roche (2006) points out that this definition of momentum only applies within Newtonian physics. For instance, in the special theory of relativity, momentum is defined as $\boldsymbol{p}=\gamma m\boldsymbol{v}$, where $\gamma = 1/\sqrt{1-v^2/c^2}$ and c is the velocity of light, while the value of the momentum of the massless photon is $p=h\nu$ in quantum physics. As a generalisation, Roche suggests that momentum be introduced in reference to impulse: "The momentum of a body will be defined as the capability to generate an impulse as it stops" (p. 1027).

force is always accompanied by an equal, but opposite, reacting force: "Force is simply the flow of the conserved "stuff", momentum, from one place to another."

As we have seen, Osborne (1984) argues that the concept of *momentum* is a central part of children's gut dynamics, even though it often gets labelled incorrectly—from the point of view of physics—as "force" through the children's exposure to lay dynamics. The idea that physicists' dynamics resonates with children's gut dynamics with regard to momentum has received empirical support. Through simple experiments, Raven (1967) provides evidence that young children, down to the age of 5 years, have developed an intuition of momentum, even before they have grasped the ideas of mass and velocity. In addition, Espinoza (2004) conducted a teaching experiment at high school level, where he compared traditional mechanics teaching, where the concept of force is introduced before momentum, to a novel approach, where momentum was introduced before force. First, in a pretest, he found that the pupils performed better at questions relating to momentum than at questions related to force. Second, while the pupils' success in mechanics activities relating to momentum was not affected by the order of teaching, the pupils that were taught momentum first benefitted in their understanding of force, lending support to the view that momentum fits better with the students' intuitions than force. Based on these findings, Espinoza provides cognitive justification for introducing momentum before force in undergraduate physics teaching, reinforcing previous formal arguments relying on force being subordinate to momentum in modern physics.

Use of Momentum in Everyday Language

Apart from its use as a physics term, momentum has found its way into everyday English by means of metaphor, thereby contributing to pupils' lay dynamics, in addition to their gut dynamics (Osborne 1984). Within the field of *cognitive linguistics*, Gibbs Jr. and colleagues have developed their ideas of a *momentum image schema* (Gibbs and Colston 1995; Gibbs et al. 2004) that applies also to fields outside of physics:

> Image schemas have internal structure and can serve as the embodied basis for many abstract, metaphorical concepts. Consider the following utterances:
> *I was bowled over by that idea.*
> *We have too much momentum to withdraw from the election race.*
> *I got carried away by what I was doing.*
> *We better quit arguing before it picks up too much momentum and we can't stop.*
> *Once he gets rolling, you'll never be able to stop him talking.*
> These utterances reflect how the image schema for MOMENTUM allows discussion of very abstract domains of cognition such as political support, control, arguments, and talking in terms of physical objects moving with momentum. We can predict important aspects of the inferences people draw when understanding these sentences given what is known about 'representational momentum' (RM) from cognitive psychological research (Gibbs and Colston 1995, p. 371).

Here, Gibbs and Colston (1995) provide examples of how the idea of momentum is used in different domains of everyday language, either in explicit utterances or as an underlying momentum image schema. As another example, the opening quote of this article shows how momentum, or "the Big Mo", was used by former US President George Bush (Sr.) in political campaigns in the early 1980s, specifically pointing out the parallel to its use in sports. Cognitive linguistics and the ideas of image schemata and conceptual metaphor are described in more detail in the "Theoretical Framework".

In addition to its use in physics and colloquial English, momentum has also been given particular meanings in other academic disciplines outside physics. Above, Gibbs and Colston (1995) refer to "representational momentum", which was introduced by cognitive psychologists Freyd and Finke (1984) for the phenomenon that subjects conceptualise their interaction with a series of static visual representations of objects at different angles as sustained rotational motion. Other examples of "semi-formal" use of momentum include:

- "Psychological momentum" in sports (Iso-Ahola and Mobily 1980), relating to ideas of gaining psychological power over your competitor as you win a first game in tennis, having a "hot hand" in basketball or being on a "lucky streak". The idea has also been related to the notion of "flow", as introduced in psychology by Csíkszentmihályi (1996).
- "Behavioural momentum", as a notion of resistance to change in psychology, introduced in the study of the behaviour of pigeons (Nevin et al. 1983). This should be compared with diSessa's (1993) idea of generalised momentum as the continuation of whatever is happening.
- "Momentum strategies" in finance, which involve investing in objects that have a history of increasing prices or earnings, "winners", as opposed to trying to identify undervalued objects, "losers" (Chan et al. 1996).

In this way, "momentum" has come to be adopted in many different domains and in all of them with different, locally sanctioned meanings.

Within physics education research, Itza-Ortiz et al. (2003) investigated the awareness of the different meanings in physics vs. everyday language of three terms, "force", "momentum" and "impulse", among 154 non-science majors taking an introductory university physics course at Kansas State University. At presurveys, one for force and another for momentum and impulse, prior to the introduction of the terms in teaching, the students were asked to write three sentences for each of the terms, involving the terms or variants of them. At postsurveys, the students were presented with four example sentences from the peers' presurveys and asked to explain similarities and differences between how the words are used in the given sentences and in physics. The postsurvey results were compared to results of a test of their conceptual understanding of the topic, given at the same time. As a result, most of the students did not manage to explain satisfactorily how everyday language differed from physics language with regard to the three words, which also correlated with lower scores on the test of their conceptual understanding. However, while everyday meanings of force and impulse, e.g. "my parents forced me to go to college" or "my sister is an impulsive shopper" (p. 332), differ substantially from the interpretation in physics, this was not found to be the case for momentum:

> The everyday meaning of the term [momentum] is quite similar to its physics meaning. It appears that due to this similarity in meanings, students are more likely to explain the physics meaning of the term momentum. For instance, when asked to explain the meaning of this term, one student said, "When someone is running, he has mass and speed, he is creating momentum." /…/ Thus, the word *momentum* seems more intuitive to the students. They might not define it as velocity times mass, but they always relate it to motion (Itza-Ortiz et al. 2003, p. 332).

They conclude that asking students to compare everyday and physics meanings of words may be helpful in learning the physics meanings. A teaching approach exploiting similar ideas has been used when introducing "heat" in secondary teaching, explicitly separating "science heat", related to energy in transfer, from "everyday heat", the sensation of hotness (Wiser and Amin 2001).

Physical Quantities in Different European Languages

Table 1 shows the names of a few physical quantities, including "momentum", in English, German, French and Swedish. A number of things may be worth noting. First, in all four languages, there are several alternative terms for some of the physical quantities, which is somewhat surprising, given the strong emphasis on standardisation of nomenclature within the science community. In addition, English and French tend to share words of a Latin origin (e.g. "force" and "velocity"/*velocité*), while German and Swedish use Germanic words to a larger extent (e.g. *Kraft/kraft*). Entropy, and its similar corresponding terms across the languages, is a Greek neologism introduced by Clausius in the nineteenth century. Further, even though terms have been borrowed across the languages, this has not been done in a consistent way. For instance, "impulse" in English corresponds to *Kraftstoß* in German, while the English "momentum" translates into *Impuls* in German, which may lead to confusion.

If we take a closer look at "momentum", the main focus of this article, English is in fact the odd one out, since the other three languages make use of expressions translating into quantity/amount of motion/movement, as a parallel to "amount of substance". Interestingly, in his analysis of Newton's *Principia*, Hecht (2003, p. 487) notes that "Newton refers to mass times velocity on one page as *quantity of motion* and on another as *momentum*". "Moment", in contrast, sharing its Latin root with "momentum" referring to motion, is used consistently across the languages to refer to rotational motion, giving rise to, among other combinations, curiosities such as an alternative expression for angular momentum in English: "moment of momentum".

In their study related to the abovementioned, Itza-Ortiz et al. (2003, p. 332) found that 59 % of the presurvey sentences using force involved the word as a verb, e.g. "I forced the box into the closet" or "My parents forced me to go to college". Further, in their analysis of Mexican undergraduates' interpretation of different meanings of force, *fuerza* in Spanish, they found that the students often came up with sentences involving the corresponding verb, *forzar*. They speculate that disambiguation of force as a noun and a verb would be easier in languages where they correspond to words with different roots and give the example of German, where the noun and physical quantity, as we have seen, are *Kraft*, while translating "my parents forced me to go to college" might involve the unrelated verb *erzwingen*.

Table 1 Comparisons of the names of some physical quantities across English, German, French and Swedish

English	German	French	Swedish
Force	*Kraft*	*Force*	*Kraft*
(Linear) momentum	*Impuls* (*Bewegungsgröße*) (*Bewegungsmenge*)	*Quantité de mouvement*	*Rörelsemängd*
Impulse	*Kraftstoß*	*Percussion mécanique*	*Impuls*
Torque (US physics), moment, moment of force (UK/US mechanical engineering)	*Drehmoment*	*Moment d'une force*	(*kraft-*/*vrid-*) *moment*
Angular momentum, moment of momentum, rotational momentum	*Drehimpuls*	*Moment cinétique*, *moment angulaire*	*Rörelsemängdsmoment*
Amount of substance	*Stoffmenge*	*Quantité de matière*	*Substansmängd*
Entropy	*Entropie*	*Entropie*	*Entropi*
Velocity	*Geschwindigkeit*	*Vitesse, vélocité*	*Hastighet*

In parallel to the use of *rörelsemängd* for the physical quantity in Swedish, the word "momentum" has recently been borrowed into Swedish colloquial language from English in domains such as sports, politics and finance. As we will see, *rörelsemängd* is confined to the science and science education domains, while "momentum" has not yet entered into formal Swedish science language, so they are used in different domains without much overlap.

Purpose of the Research

As shown in the "Introduction", pupils' intuitive interpretations of their physical interaction with the world, their gut dynamics, fit well with physicists' dynamics with regard to the notion of momentum. This stands in contrast to, for instance, "force", which has been found to be more challenging and counterintuitive. In the present research, we focus on the relation between a physics interpretation of momentum and how the word has come to be adopted in written, everyday language—in lay dynamics. In particular, in this study, we investigate the metaphorical use of "momentum" through the analysis of openly available text corpora, samples of everyday language in different domains. In a first study, we analyse the occurrences of "momentum" in English and Swedish in Europarl (2013), a text corpus from the European Parliament, and compare with a broader range of genres in the British National Corpus (BNC) (Burnard 2007). In a second study, we turn to the use of "momentum" in Korp, a Swedish text corpus, including language from daily journals, magazines, blogs, etc. In particular, the investigation was guided by the following research questions:

- How does the metaphorical use of "momentum" in domains outside physics, in English and Swedish, align with physics meanings of the word?
- Is there a trend towards increased use of "momentum" outside physics?
- Does the use of momentum in everyday language support early introduction of the word in physics teaching?

Theoretical Framework

A text corpus (corpora in plural) is a sample of text stored in a database and studied within the field of *corpus linguistics*. Corpora are the main tools to study language use, in particular when we are interested in features such as frequency, collocations or constructions of a word (Hunston 2002). Following the general technological development, corpora are stored electronically and many of them can be accessed over the web and be downloaded to your own computer, which simplifies corpus search considerably.

Corpora are collected for different purposes. Specialised corpora may focus on a specific text genre, a specific time period or a specific speech situation, while corpora that cover many varieties of a language are referred to as general. Properties such as balance and representativeness have been put forward as desirable for general corpora but are hard to achieve (see, e.g. Biber 1993), and so any corpus will be biased in some way.

For this investigation, where we look at the behaviour of "momentum", a relatively rare word (especially in Swedish), size and ease of access were judged to be the most critical properties. Europarl (2013) is one of the largest parallel corpora in existence with more than 40 million words for both English and Swedish (Koehn 2005). Europarl data is taken from the proceedings of the European Parliament and as such is biased towards political language. It covers the years 1996–2011. For comparison, we use the British National Corpus of 100

million words accessed over the BYU web interface (Davies 2004). This corpus is more balanced but reflects an earlier time period (1980–1993). For Swedish, we also used all data, more than one billion words, from the web corpus Korp provided by the Swedish Language Bank, Språkbanken (2013), administered at Gothenburg University.

The field of *cognitive linguistics* represents a multidisciplinary approach to the study of the relation between language and thought, which emphasises the role of embodied experiences in language use. Examples of research in cognitive linguistics include the work on conceptual metaphor by Lakoff and Johnson (1980, 1999) and Talmy's (1988) development of force dynamics.

Based on observations that metaphors are a ubiquitous feature of language—and other pioneering work on metaphors (e.g. Reddy 1979; Richards 1939)—Lakoff and Johnson (1980, 1999) introduced the theory of *conceptual metaphor*, arguing that we construe and talk about abstract phenomena by implicit comparison to more concrete experiences. In particular, Lakoff and Johnson (1999) argue that basic concepts such as time, cause, change, state and purpose are typically understood by means of conceptual metaphor. Overall, they identify two different ways in which events are metaphorically construed, one of which they call the *location event structure metaphor*, a conceptual metaphor in which states are construed as locations. Take for example "Harry is *in* love". Here, the abstract concept of love is construed as a concrete container and the preposition *in* allows Harry to be located in this emotional state. Aligned with states construed as locations, changes of states may be conceived of as movements into or out of locations (e.g. "I got out of my depression") and caused changes are construed as forced movements (e.g. "The tragedy pushed me into deep sadness"). The other conceptual metaphor for understanding events Lakoff and Johnson call the *object event structure metaphor*. In this case, abstract attributes or states are construed as possessions (e.g. "He *has* a lively spirit"), changes of state or attribute are construed as movement of possessions (e.g. "He *got* a cold") and caused changes of state are seen as forced transfer of a possession (e.g. "The music *gave* me a headache"). Further, Johnson (1987) developed the idea of *image schemata* as a way to characterise our mental representations of sensory and perceptual experiences grounded in our daily bodily interaction with the world. For instance, both "Harry is in love" and the more concrete "Harry is in the kitchen" rely on a container image schema, where we talk of Harry as located metaphorically in a certain state of mind and literally in a physical room, respectively. As seen in the "Introduction" and of particular interest to our studies here, Gibbs and Colston (1995) have analysed "momentum" from the point of view of conceptual metaphor and image schemas.

Another cognitive linguistic approach to the study of the relation between language and thought with regard to interaction of physical objects is *force dynamics* developed by Talmy (1988). He set about to demonstrate the pervasiveness of force-dynamic patterns in human thinking. Consider for example "the ball kept rolling". The expression may be analysed from the perspective that the ball is striving for rest but forced to move on by something stronger. Such thought patterns may also be applied metaphorically outside the domain of interaction and motion of physical entities, as in "my parents forced me to go to college" (Itza-Ortiz et al. 2003, p. 332), introduced above.

Recently, the fields of corpus linguistics and cognitive linguistics have come closer to each other. This trend has largely been driven by an interest in cognitive linguistics to analyse authentic language use and the need to make methods of data analysis more explicit (Newman 2011; Tummers et al. 2005), and a recognition of the potential in quantitative approaches to cognitive linguistics (Sanford 2008).

With the rise of sociocultural perspectives on learning, there has been an increasing interest in the role of language in science education as a tool or resource for learning (e.g. Lemke

1990). Although most research has focused on the dynamics of language in discourse, as we saw in the "Introduction", there has been an interest in the influence of semantics and the structure of language on science learning. For instance, Sherin (2013) has explored how we may use computational approaches in the analysis of students' language in relation to their conceptualisation of seasonal changes.

The conceptual metaphor perspective has been adopted in science education and, in particular, in physics education research (e.g. Amin 2009; Amin et al. 2012 Andersson 1986; Brookes and Etkina 2007, 2009; Jeppsson et al. 2013; Scherr et al. 2012). For example, Amin (2009) presents a conceptual metaphor analysis of the scientific and lay use of the term "energy" based on an analysis of *The Feynman Lectures on Physics* (Feynman et al. 1989) and a sample of 200 sentences involving energy in the BNC. Amin concludes that energy is construed metaphorically in terms of concrete source domains such as schemas of containment, possession, movement along a path, force dynamics and part-whole relations. In addition, in talking about the energy *in* an object or an object *having* energy, we make extensive use of the location and object event structure metaphors in relation to this abstract concept.

In parallel to Amin (2009), Haglund et al. (2010) made use of text corpora as a way to collect data for an investigation of different senses of the word entropy. Five distinct different senses of entropy were found in the analysis, all related to each other in a semantic network. According to Lakoff (1987), different senses of a word may be derived from different image schema transformations or metaphorical extension from a sanctioning sense, in this case, the interpretation of entropy in statistical mechanics. Similar mechanisms may have been at work in the metaphorical extension of momentum in everyday language and in academic disciplines outside physics.

Within the presented theoretical framework, we have conducted two different empirical studies of the metaphorical use of "momentum". The first study investigates the use of "momentum" in non-science domains in English, showing relative frequencies of momentum in different domains and in different sentence constructions. The second study shows how metaphorical use of "momentum" has come to enter the Swedish language, with a focus on assessment of the physics adequacy of identified sentences.

Study 1—Metaphorical Use of Momentum in English

Method

In this study, we analysed the use of "momentum" in English using the English part of the parallel English-Swedish Europarl corpus and the BNC as our data. For the BNC, we used the BYU interface (Davies 2004) over the web to see the distribution of "momentum" in different subcorpora and identify verbs that collocate with "momentum". For the Europarl (2013) data, we extracted all occurrences of "momentum" with their complete sentence contexts and Swedish translations and then analysed the data manually. As the European Parliament is a forum for political debate, it can be assumed that all uses are metaphorical, something which was also found in the data.

Results

Distribution over Genres and Time

Table 2 shows frequency data for the complete corpora and some subcorpora. We wanted to see whether there is a difference between the two corpora and, in the case of the Europarl

corpus, whether there has been an increase in the use of "momentum" over time. We can see that there are differences in relative frequencies across the two corpora, although they are small. "Momentum" is more common in Europarl than in the BNC but only by a factor of about 1.5 (15 instances per million words in Europarl compared to 9.78 in BNC).

A small increase can be seen over different years in the Europarl data; the word "momentum" is more frequent in the more recent 4-year period than in the 1990s. The Europarl corpus is homogenous though, and the variation between individual years is small. Also, the change from 1 year to the next is negative for several years, for example for 1999–2000 or 2007–2008.

In contrast to Europarl, BNC covers different genres and the difference between genres is occasionally large. Not surprisingly, the highest relative frequency is found for Academic texts of the subgenre Natural Science (76.05) where almost all instances manifest the physics usage. Other sub-genres have no or just a few instances. The Newspaper genre is close to the average for the full BNC (9.46 as compared to 9.78) and illustrates metaphorical usage in several domains such as politics, sports, economics and arts.

Table 2 Absolute and relative frequencies of "momentum" in different English corpora and subcorpora

Corpus	Absolute freq.	Relative freq. (items per million)
BNC total	941	9.78
BNC academic	191	12.46
Nat. science	84	76.05
Law	44	9.53
Humanities	34	10.32
Social sciences	22	5.21
Engineering	4	5.89
Medicine	3	2.02
BNC non-academic	288	17.46
Nat. science	107	42.95
Law	68	15.28
Social sciences	39	9.40
Arts	37	9.94
Engineering	36	30.34
Medicine	1	2.82
BNC newspaper	99	9.46
BNC miscellaneous	200	9.60
BNC magazine	75	10.33
BNC fiction	65	4.09
BNC spoken	23	2.31
Europarl total	828	15.03
1996–1999	165	13.01
2000–2003	194	13.19
2004–2007	213	17.08
2008–2011	256	16.81

Metaphorical Use of "Momentum" in English in the European Parliament

A close study was performed on the Europarl data. As we wanted to compare the use of "momentum" in English and Swedish, this study used the sentence-aligned English-Swedish parallel corpus, giving a total of 704 English sentences with "momentum" and 18 Swedish sentences. In 14 of these pairs, the English and Swedish "momentum" instances were direct correspondences in translation. Thus, it can safely be said that the use of "momentum" by Swedish speakers and Swedish translators in the European parliament is rare and not sufficient to undertake an analysis. Much more common as equivalents of English "momentum" are words such as *drivkraft*, *drivande kraft* (propelling force), *fart* (speed), *slagkraft* (forcefulness), *kraft* (force), *dynamik* (dynamics) and *styrka* (strength).

The English instances were analysed both syntactically and semantically. The findings are summarised in Table 3, which is primarily grouped by semantic types with typical syntactic constructions listed for each group. Each construction is given in its active, declarative variant, and frequencies are given for the most common constructions. The counts include other variants of the constructions as well, such as passive, interrogative or participial variants.

We refer to the object or process that is ascribed momentum as a THEME. There is a large variation in the corpus with respect to possible THEMEs. It seems actually that anything that can be taken to move in a metaphorical sense can be associated with momentum. Some nouns and noun phrases that appear in the corpus are adaption, administration, ambitions, area of free movement, cause of sustainable development, changes, climate policy, competition, debate, dialogue, enlargement, European integration, European social agenda, growth, ideas, implementation, initiation of projects, institution, internal market, management, negotiations, policy, process, productivity, reform, relations, student and researcher mobility. Quite often, the theme is implicit in the clause where "momentum" occurs, but inferable from the larger sentence or discourse context.

Other semantic roles that feature extensively in "momentum"-constructions are those of AGENT and CAUSE. As it is not always clear whether the causation is intended or not, we lump them together for some constructions under the single label AGT/CS.

Often, an adjectival or other attribute is modifying "momentum" in these constructions. The most common attributes are *new* (83), *political* (41), *fresh* (13), *positive* (11) and *some* (9).

Discussion

As seen in the relative frequencies in different genres in BNC, "momentum" is still most prevalent in the context of natural sciences, but we can safely conclude that it is also established in some non-science domains, such as politics.

It appears that most of the semantic types that we find for the metaphorical use of "momentum" in this political context can apply to the physical sense too, although perhaps in different proportions. If we imagine replacing the themes with physical objects, many of them come across as adequate from a physics point of view. For instance, replacing "economic growth" with "the car" in "economic growth has gained momentum" makes perfect sense. Similarly, "an initiative would indeed boost momentum in the region" could be altered into "a more powerful engine would indeed boost momentum in the car" without much problem. Expressions involving "enhancing" or "requiring" momentum come across as less adequate from a physics point of view, due to their teleological and value-based implications. Similarly, the causal use of momentum in "Now the recovery has picked up speed and is driven by its own momentum" is not in line with the physics view, as is the case of "On the contrary, it created new momentum", which seems to defy the idea of momentum as a conserved quantity.

Table 3 A semantic typology and frequencies of "momentum" constructions in English Europarl data

Semantic type	Constructions	Examples
EXISTENCE Momentum exists	*There* + be + *momentum* (25) THEME + have + *momentum* (7) Momentum + be + *there* Momentum + be + *present*	I am proud of the momentum towards Fair Trade that now exists. The Lisbon strategy is going to have new momentum. It is now time…because the momentum is there.
CHANGE Momentum changes without apparent cause	THEME + verb + *momentum*, where verb can be positive (*gain* (*34*), *gather* (*19*), *acquire*, *get*, *pick up, take up*), or negative (*lose* (35) *Momentum* + verb, where verb can be positive (*grow*, *mount*, *strengthen*…) or negative (*falter, founder, vanish, be lost, weaken, slow down*…)	Last November saw the peace process gather momentum. Economic growth has gained momentum. I think some momentum is being lost. This momentum is diminishing day by day
CREATION Something causes momentum for THEME	AGT/CS + verb + *momentum* (+prep THEME), where verb can be *create* (62), *generate* (22), *give [to]* (52) *achieve*, *bring about*, *impart [to]*, *inject [into], trigger*[a]	On the contrary, it created new momentum. We urgently need a European policy to give momentum to this sector. Now the time has come to regenerate a new momentum in the reform process.
CAUSE_TO_END Something causes momentum to come to an end	AGT/CS + verb + *momentum* (+prep THEME), where verb can be *destroy, halt, kill*…	Appointing people who are even worse than NN…will destroy the momentum and work against progress.
MAINTENANCE Something ensures continued momentum	AGT/CS + verb + *momentum* (+ prep THEME), where verb can be *maintain* (*74*), *keep up* (*38*), *keep … going* (*15*), *sustain* (*12*)	The report comes at the right moment to maintain the momentum for the in-depth revision of the Directive. Europe must now keep the momentum going.
STEPPING UP Something makes for momentum to increase	AGT/CS + verb + momentum (+prep THEME), where verb can be *boost, step up, increase, enhance*…	We are not convinced at this stage that such an initiative would indeed boost momentum in the region. The new government is encouraged to consolidate and enhance the momentum of political reform.
NEED Something needs momentum	THEME + verb + *momentum*, or AGENT + verb + *momentum*, where verb can be *need* (*15*)*, require*…	I, too, am in favour of an evaluation and of our now putting to the test/…/, but we also need new momentum. But this requires reform, it requires economic momentum, and it requires higher rates of productivity.
USE Something uses momentum for a purpose	AGENT + verb + *momentum* (+prep THEME) where verb can be *use* (*19*), *take advantage of, harness*, *make the most of*…	I believe we should take advantage of the momentum generated by the Transatlantic Agenda. I hope that we can use this momentum together for the benefit of effective European solidarity.
INFLUENCE A momentum affects something else	*Momentum* (as CAUSE) + verb + AFFECTED, where verb can be *cause, drive, enable, sweep along, transform*…	This momentum causes an increasing number of delegations to realise that it is more in their interests for the talks to succeed than to fail. Now, the recovery has picked up speed and is driven by its own momentum.

[a] Some of these verbs such as *give* also allow the dative alternation "AGT/CAU + verb + THEME + *momentum*"

Several of the most common constructions such as *maintain momentum*, *gain momentum* and *lose momentum* are more used in the everyday metaphorical language than in the physics texts. In fact, none of these verbs appear with "momentum" in the BNC Academic, natural science subcorpus, so there is a systematic difference in the pattern of language use, but we still do not think that talking about a car "gaining momentum" would be disturbing to a physicist.

Study 2—Metaphorical Use of "Momentum", *rörelsemängd* and *kraft* in a Swedish Text Corpus

Method

In study 2, we analysed sentences including the word "momentum" and compounds of momentum, such as *momentumstrategin* (the momentum strategy), in Korp, a text corpus aspiring to provide a representative sample of current Swedish language (Språkbanken 2013). Our selected sample within Korp, in turn, included all provided occurrences in daily press, in magazines and in blogs, but excluded for example fictional literature and Wikipedia entries. In addition, we analysed all occurrences of the word *rörelsemängd* (the Swedish term for momentum as a physical quantity) in the same sources and a sample of 80 occurrences of *kraft* (meaning force).

The sentences were categorised using the following classification scheme:

- Type of source. The source of the sentence, e.g. daily press, popular science magazines, the European Parliament publications, blogs or Wikipedia entries.
- The year of publication. The samples provided include entries from the period 1995 to 2013, with a bias towards more recent texts.
- Domain. The language domain of each sentence, including science, finance, politics, sports and humanities.
- Metaphoricity. The degree of metaphoricity assessed in three levels: *literal*, referring to the word as a physical quantity; *implicitly metaphorical*, where the word is used in other domains than as a physical quantity, without pointing out its metaphorical character; *explicitly metaphorical*, where the metaphorical character is indicated (for example with italics, quotation marks or cross-domain comparisons: "as they say in athletics").
- Type of metaphor. For sentences that were considered to be metaphorical, the type of metaphor used was specified, including proper names (such as the consultancy firm Momentum), Lakoff and Johnson's (1999) location and object event structure metaphors, reliance on Talmy's (1988) force dynamics or expressions involving anthropomorphisms or conceptualising the involved terms as levels on a scale.
- Adequacy. The sentence was deemed adequate if a corresponding expression involving motion and interaction of physical objects would make sense from the perspective of Newtonian physics, otherwise not.

Some examples may be useful to describe the procedure of the analysis. The sentence, "My training has broken down completely, and the little momentum I had is lost", was found to be an adequate use of the object event structure metaphor, conceptualising momentum as an object that is possessed and gets lost, in the domain of sports. In contrast, "Just when the Centre Party [a political party] is in a momentum, and can get a push upwards, there's an accidental shot from inside" was found to be an inadequate use of the location event structure metaphor in the domain of politics, since momentum is typically not something that an object

is *in*. This does not exclude the possibility of using the location event structure metaphor adequately together with momentum. For instance, we found the following expression adequate: "When a certain momentum has been reached, things start to happen faster…" Here, "a certain momentum" is construed as a location, possibly as a value on a vertical scale. Admittedly, the assessment of the adequacy is more subjective than the other categories and we chose to be conservative in excluding sentences that would come across as rather odd if they were transferred to the domain of physics. For instance, we considered the following sentence inadequate: "Our university is far from perfect and has a rocky road ahead, but shows signs of a strong momentum" since momentum cannot be "strong", but rather "large". The sentences were analysed in Swedish and translated into English in this account of the analysis.

Results

Momentum

Four hundred and thirty-one sentences including "momentum" and compounds thereof were identified in the selected text corpus. All of them were analysed using the classification scheme detailed in the "Method", but in the following account, we exclude the 59 sentences involving Momentum as a proper name (e.g. a consultancy firm), ending up with 372 sentences.

Overall, 277 (74 %) of the sentences were coded as *adequate* from the point of view of Newtonian physics. We consider this an impressive result, particularly considering our rather conservative assessment of the sentences' adequacy. Regarding the types of metaphors used, the object event structure metaphor dominates all other ones, representing 79 % of all sentences. In addition, out of these sentences making use of the object event structure metaphor, 86 % were found to be adequate, which is maybe not surprising, since we have seen that physicists are typically comfortable with conceptualising momentum as an object that you can have or contain (e.g. diSessa 1993). The three most represented domains were *politics* (138 sentences), *sports* (81) and *finance* (67), and we focus on these domains in more detail below (see Table 4).

As for politics, 77 % of the sentences were considered adequate, but only ten of them were explicitly indicated as metaphorical, possibly saying that momentum has been adopted as part of the vocabulary, without being interpreted as slang expressions. It may be further noted that several of the instances are taken from Foreign Minister Carl Bildt's personal blog, lending credibility and status to the use of the "momentum" in Swedish politics. However, we should remember the analysis of use of "momentum" in Europarl from study 1, where "momentum" in English was typically found to be translated into other words or phrases in Swedish, which goes against a widespread adoption of "momentum" in formal political Swedish.

In finance, "momentum" appears primarily in stock reports taken from daily press and blogs. Here, 72 % were found to be adequate, the slightly lower figure seemingly due to the adoption of a finance jargon from English, as in "…the stock went into a consolidation phase, where the momentum continues to fall…" Only one case was identified of explicitly metaphorical use of "momentum" in finance Swedish. The use of "momentum" in finance is further characterised by common use of compounds, such as *vinstmomentum* (profit momentum) and *momentumstrategi* (momentum strategy), relating to the established sense of momentum as a term within the domain.

The way that "momentum" has been adopted in Swedish sports commentary was actually the starting point of study 2. We had noticed that commentators had come to use the word, and there had also been a bit of press recognition that this "Americanism" had entered Swedish,

Table 4 Overview of metaphorical use of "momentum" in Swedish from Korp split up by domain

Domain	Frequency (abs.)	Adequate (%)	Explicit metaphor (%)	Object event structure metaphor (%)	Example sentences (with adequacy and type of metaphor)
Politics	138	77	7	83	…with the closing of the parliament, the coalition lost its momentum. (adequate, object event structure) But my feeling still is that the movement reached its momentum in the beginning of the nineties. (inadequate, location event structure)
Sports	81	93	15	94	The training has broken down completely and the little momentum I had is lost. (adequate, object event structure) The Cards rode on a wicked momentum all the way to the World Series title. (inadequate, object event structure)
Finance	67	72	1	63	German DAX has started to lose momentum and seems to be falling back. (adequate, object event structure) In order to build momentum in a commoditised industry… your main task has to be to focus on the price… (inadequate, object event structure)
Other/no category	96	57	5	65	When they eventually get going, they have lost momentum and do not quite find their way into the concert again (adequate, object event structure) What happened was simply a momentum, which, when it had picked up speed, was found to be hard to stop. (inadequate, object event structure)
Total	373	75	7	79	

and was not always received favourably. Therefore, we were particularly excited to see how the use of "momentum" in the sports domain turned out. In fact, 93 % of the sentences were adequate from a physics point of view and 94 % of them relied on the object event structure metaphor. Another characteristic is that quite a few (15 %) of the sentences were explicitly metaphorical. For instance, in an interview from 2007, the journalist comments a team representative's use of the word: "We had talked about it, that the start is important in order to get 'momentum', he continues, in Swedish, but with a word borrowed from ice-hockey English". It seems as if Swedish sports journalists are still cautious about using "momentum" in their reports and that it gives a slang impression, which opens to sarcasm: "There's a certain hockey expert, we can call him 'momentum'…", alluding to his frequent use of the word.

Due to bias in the text corpus, for instance, many of the sentences in the finance domain are taken from reports made in 2008 to 2009, it is difficult to say for sure that the use of

"momentum" has increased in Swedish during the covered period from the corpus data. However, as shown in Fig. 1, the trend from 2003 onwards speaks in favour of an increase and it is clear that the word was borrowed from English rather recently in all domains.

Rörelsemängd

While "momentum" was typically used in domains outside science, the use of *rörelsemängd* (momentum as a physical quantity) was confined almost exclusively to the science domain, with a meagre result of 14 identified sentences, most of which were found to be literal and adequate. The exclusion of Wikipedia entries affected the analysis since there were a couple of hundred occurrences of *rörelsemängd* in relation to other science terms, which were not touched upon here. An exception to the typical scientific language was the explicitly metaphorical "The elderly clientele needed access to their 'daily essential amount of exercise *[rörelsemängd]*' in order not to get stiff and bound to their beds", which, however, is unrelated to momentum as a concept. It may be concluded that as opposed to "momentum" in English and increasingly also in Swedish, *rörelsemängd* is not a common word in everyday Swedish and is rarely used metaphorically outside science.

Kraft

In contrast to both momentum and *rörelsemängd*, *kraft* (corresponding to force as a noun and physical quantity) is a very common word in everyday Swedish. As a reference, we chose to analyse 80 sentences in Korp taken from Göteborgsposten, a daily journal, in 2012, including the word *kraft*. Only four of these sentences were found to refer literally to force as a physical quantity (it may even be questioned whether force as a physical quantity is more literal than other senses of the word). Fourteen of the sentences were considered as adequate from the physics perspective, and 42 of them made use of the object event structure metaphor, e.g. "It is a meditative experience that gives joy and force". Hence, the use of *kraft* as a noun in Swedish seems to follow the impetus-like pattern of "force" in English, something that objects may have. Another characteristic is that 26 of the sentences involve idiomatic expressions,

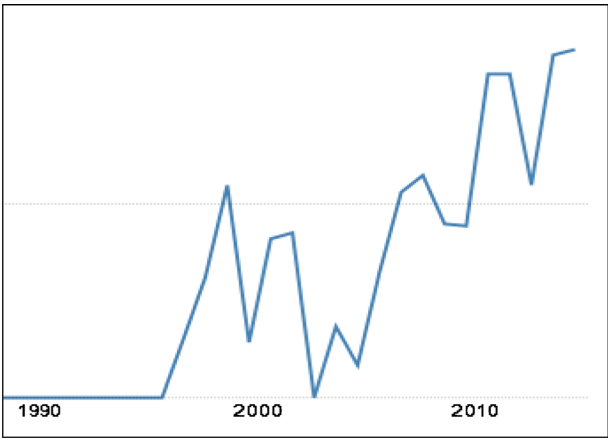

Fig. 1 A trend diagram of the relative frequency of "momentum" in Swedish generated by the Korp web interface on 15 November 2013 for all corpora with the caveat that 16.2 % of the data lacks a time stamp (the *dotted horizontal line* indicates 0.5 instances per million words)

corresponding to, for instance, “put force behind one’s words”, “by her own force” or “come into force”, which often do not align with force as a physical quantity.

Discussion

As in the case of metaphorical use of “momentum” in English in study 1, we found that the metaphorical use of the word in Swedish is largely adequate from a physics point of view. In addition, there is a striking contrast with the exclusively literal use of the corresponding physics term *rörelsemängd* and the colloquial use of *kraft*, meaning force, which is typically inadequate from a physics point of view. Out of the studied domains, it is not unreasonable to think that the domain of sports is the one that reaches students to the greatest extent. It is therefore particularly interesting that sports is the domain where we see the language use that is most in line with that of a physicist. The increasing trend in Fig. 1 and the common use of the word without explicit metaphorical indication give us reason to believe that “momentum” has come to stay in colloquial Swedish language, at least in certain domains.

General Discussion

In a concluding discussion, we first briefly revisit the research questions in the light of previous literature and our two conducted studies, then draw some implications for education and finish with a method discussion, where we reflect on how tools from cognitive linguistics and corpus linguistics may serve the field of science education research.

How Does the Metaphorical Use of “Momentum” in Domains Outside Physics, in English and Swedish, Align with Physics Meanings of the Word?

In the overall analysis of occurrences of “momentum” in English in the British National Corpus, we saw that the word is cut out most frequent in natural science domains but also used metaphorically in other disciplines, such as law. In the analysis of Europarl data, we also found the metaphorical use of “momentum” to be established in European parliament documents in English. In the more detailed semantic and syntactic analysis of sentences involving “momentum” in Europarl, we found that most constructions, involving for instance existence, and change of momentum, align well with physics language. This lends support to the conclusions with regard to momentum by Itza-Ortiz et al. (2003, p. 332) that “The everyday meaning of the term is quite similar to its physics meaning”.

The metaphorical use of “momentum” in Swedish was found to follow the pattern of the metaphorical use of the word in English. Most occurrences were found in the domains of politics, sports and finance, and a majority of these were deemed adequate from the point of view of the meaning of the word “momentum” as a physics term in English. In contrast, metaphorical use of *kraft* in Swedish, meaning force, was found to be largely inadequate, paralleling the findings of Itza-Ortiz et al. (2003) with regard to English-speaking students’ language in relation to “force”.

Is There a Trend Towards Increased Use of “Momentum” Outside Physics?

The Europarl data analysed in study 1 shows that metaphorical use of “momentum” was established in European political English in the late 1990s, but there is also a slight positive trend of increasing usage. Furthermore, the scarce occurrence of “momentum” in the Swedish

translations of the corresponding texts shows that the word has not yet been adopted widely in formal political Swedish. The Korp data of study 2 shows that "momentum" was borrowed into Swedish rather recently and that there is an increasing trend of metaphorical use in many domains, such as sports, finance and also politics. In Swedish, "momentum" is used in informal, non-scientific genres, such as blogs, and with overall frequencies of around 0.5 instances per million words, to be compared with 10–15 instances per million words in the English corpora. In contrast, in science, the literal use of the corresponding term *rörelsemängd* is rarely replaced by "momentum" in Swedish.

Does the Use of Momentum in Everyday Language Support Early Introduction of the Word in Physics Teaching?

Our investigation shows that the use of "momentum" in everyday language—in English and in Swedish—fits well with the physics meaning of the term. In Osborne's (1984) framework, this means that there is an overlap between physicists' dynamics and the lay dynamics with regard to momentum. Although Osborne points out that "momentum" is often mislabelled as "force", we have found a productive role for the lay dynamics of "momentum" from the point of view of science education. This finding complements the previously identified close relation between, physicists' dynamics and children's and pupils' gut dynamics involving momentum (Espinoza 2004; Raven 1967). In contrast, *kraft*, corresponding to "force" as a physical quantity, was found to be used in a wide range of senses in everyday Swedish, including many idiomatic expressions, which do not adhere to the physics sense of the word. Overall, this mutual agreement between gut, lay and physicists' dynamics lends support to the proposal to introduce "momentum" in science teaching at an early age (Osborne 1984) and prior to the introduction of the more counterintuitive notion of "force" (Espinoza 2004).

Educational Implications

In line with Osborne (1984) and Espinoza (2004), we argue for an early introduction of the word "momentum" in physics teaching, in English and in Swedish. How can this be done in practice?

From the perspective of gut dynamics, we would encourage taking advantage of children's intuitions and embodied experiences of interaction with physical objects. In line with the empirical findings of Raven (1967), children embrace a productive intuition of momentum at an early age, saying that the bigger and the faster an object, the more "oomph" it has. Related to the idea of a "generalised momentum" (diSessa 1993), large and fast objects will tend to continue doing whatever they do, a basic idea of inertia.

As for the use of momentum in everyday language, we find an explicitly semantic approach, where teachers point out that the thing that large and fast objects have or contain should be called "momentum" rather than "force" to be the most attractive approach (Brookes and Etkina 2007; Osborne 1984). Given the largely adequate metaphorical use of momentum in everyday English, as found in this study, it is likely that pupils will be able to relate to and adopt the word in the science classroom. For words such as "force" or "heat", which have distinctly different meanings in science and everyday language, pupils may benefit from being confronted with such semantic proliferation (Wiser and Amin 2001). Due to the more uniform use of momentum across language domains, pupils' understanding of momentum as a physics concept can be supported by exposure to authentic examples of everyday expressions involving the word in a more direct way. For instance, from a text corpus of sentences involving "momentum", pupils could be asked to assess their adequacy from a physicist's point of view, as a parallel to the tasks designed by Itza-Ortiz et al. (2003), presented in the "Introduction".

Once the idea that objects in motion have momentum has been established by relating it to pupils' gut dynamics and lay dynamics, the notion of force can be introduced in science teaching in reference to momentum (Espinoza 2004), in terms of "Net force changes momentum" (Osborne 1984, p. 508).

As we have seen, one advantage of momentum, as opposed to force, is that it lends itself to a substance-like interpretation in conceiving of momentum conservation and momentum flow (diSessa 1980; Herrmann and Schmid 1985). However, there are subtleties to the matter, including that there are other physical quantities in mechanics that can be conceptualised as substance-like entities, such as energy (Amin 2009; Falk et al. 1983). Indeed, students have been found to have difficulties disambiguating momentum from energy or kinetic energy, focusing on being able to carry out calculations, rather than necessarily developing their conceptual understanding (Singh and Rosengrant 2003).

Turning to a Swedish physics teaching context, there are many possible ways to make use of students' intuitions of momentum and the increasing—albeit not fully established—use of the word in everyday Swedish. The term *rörelsemängd* is not related to in the Swedish curriculum for the compulsory school (Skolverket 2011), so students are typically introduced to the concept of momentum in their first physics courses (grade 10 or 11) if specialising in the natural science or technology programmes in upper secondary school. Against the background of the findings in study 2, it is not unlikely that such students have encountered metaphorical uses of "momentum" outside school. In particular, they may have come across it in sport commentaries, where it is used in a way well aligned with the meaning of the word in physics, and often indicated as explicitly metaphorical. In contrast, we found an almost exclusively literal use of the word *rörelsemängd* in Swedish, within the domains of science and technology, indicating that students are not likely to have heard that term before it is brought up in formal instruction.

One tempting and radical option would be to replace *rörelsemängd* with *momentum* in Swedish physics teaching completely. However, there are drawbacks to such radical change. Apart from the problem of breaking continuity of the established use of *rörelsemängd* as a scientific term, as we saw in the "Introduction", "moment" is used to denote rotational motion in Swedish. We would like to avoid confusion between these terms and conjunctions, paralleling "the moment of momentum" in English. In addition, even if students have not come across *rörelsemängd* as a term, it is a compound of two words, which correspond to "movement/motion" and "amount" and would be familiar to the students. Less radically, but still taking advantage of the assumption that students have encountered "momentum", for example in sports commentaries, teachers could point out that it is the English term corresponding to *rörelsemängd*. This approach could be used in physics teaching also in other countries, even though we do not know if the metaphorical use of momentum has been borrowed into languages other than Swedish or if the corresponding technical terms for the physical quantity are found in everyday language.

Method Discussion

In the present research, we have used tools from corpus linguistics and cognitive linguistics with the aim of showing how they may inform the theory and practice of science education. First, we want to point to the free and user-friendly access to large collections of text corpora that are available through the Internet. In addition, the possibility attain representative samples of current everyday language is increasing, as web corpora including blogs and Wikipedia articles are regularly collected and made available, though not always through well-known access points such as BYU or Korp and still with a focus on written language.

Once relevant text corpus data has been selected, computational linguistics offers many different approaches to data analysis. In study 1, we give examples of the possibilities in

calculating relative frequencies of occurrences of words and collocations of several words. As mentioned, Newman (2011) points out that computational analysis of corpus data may strengthen the validity of claims in cognitive linguistics and show subtle patterns in language use that are difficult to identify through qualitative analysis.

One reflection after having engaged with different text corpora is that analysis of moderately common words seems to be most fruitful. In study 1, we found few occurrences of "momentum" in the Swedish Europarl sample and, similarly, we did not come across many instances of *rörelsemängd* in study 2. Therefore, there was not much data to analyse and it was difficult to draw in-depth conclusions. On the other hand, the wealth and complexity of different semantic and syntactic patterns in relation to "force" or the corresponding *kraft* quickly became unmanageable. The couple of hundred instances of "momentum" in the English sample of Europarl and in BNC, and of "momentum" in the Swedish Korp seemed to strike a good balance.

Admittedly, sample sentences in a text corpus do not reflect language as it is used in authentic school settings in a very adequate way. Nevertheless, glancing at the everyday language from different time periods provided in text corpora might also be considered in educational research, as a cheaper and more efficient approach than, for example, traditional video and voice recording and transcription. This provides interesting insight into how lay dynamics may influence the pupils' gradual adoption of sanctioned physicists' dynamics.

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