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Review and Discussion: E-learning for Academia and Industry

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Abstract. This paper presents a high level review and discussion about e-learning and proposes the use of interactive learning as a recommended method for staff training in industry and academia. Interactive learning is focused on the integrated e-learning and face-to-face learning to ensure that the process of learning can stimulate learners' interests, report their progress and have tutors to provide their feedback and guide learners to the expected targets. Learning activities and varieties have been illustrated with discussion about how industry and academia can use interactive learning. Five successful examples of interactive learning to demonstrate the effectiveness of interactive learning. Positive impacts have been reported in RBS, SMEs using SAP, University of Cambridge, University of Greenwich and Leeds Beckett University to support the positive outcomes for learners and trainers. Future directions have been discussed, particularly the use of emerging services can enhance the learning experience and satisfaction for learners and trainers.

Keywords: E-learning for academia and industry; Interactive learning; Interactive learning case studies how to use interactive learning.

1. Introduction

Investment in human resources is essential to the development of human capitals, whereby countries and organizations that have invested in human capitals are in a better position to acquire long-term benefits (Schultz, 1961; Reynolds, Caley, & Mason, 2002). This is also relevant to industry, since employees need to keep their skills and knowledge up-to-date. A moving organization is the one that invests in people and ensure that all employees' skills are up-to-date to stay competitive (Bahrami, 1996 and Gould, 2009). By offering staff training, benefits for organizations are as follows. First, employees can complete their tasks quickly and efficiently without making mistakes that can cost the organizational reputation and financial loss (Sveiby, 1997). Second, products and services can be enhanced since the team for research and development, sales, marketing and operations have better competency, skills and knowledge to ensure that products and services are continuously improved (Day, 1994). Third, the organization can design and develop better strategies, new products and services as a result of the improved level of overall competency and collaboration (Gould, 2009). An organization can become an learning organization since the employees can learn from their previous errors, accelerate their progress and improve on their work performance as individuals and units. More time and effort can be used on development of the forward-thinking plans to reduce costs, errors and improve on collaboration, team work and market strategies (Treacy & Wiersema, 1997). In this way, it offers a greater level of competitiveness over their rivals. Human capital can include knowledge, skills, competencies, relationships and creativity implicit in an organization's workforce (Reynolds et al., 2002).

To facilitate better learning and training activities, the use of online resources have been blended successfully with education. One of these areas is known as e-learning, which offers the online delivery of information, communication, education and training (Sloman, 2001). Using electronically-based approaches, learning and training can be conducted at anywhere and anytime. It can save operational costs including costs for accommodation, travel and booking of physical classrooms that require all the employees to attend physically. Some forms of learning activities can be completed offline, such as watching the training videos, completing assignments and rehearsing skills that were acquired at the training workshops. The e-learning education can be improved significantly with the systematic approach to ensure that learners' progress can be reviewed at check points and demonstrate that there is an improvement on the learners' competency of knowledge and skills (Rothwell & Kazanas, 2011). One of such approaches is the use of blended learning to combine the use of classroom teaching and online learning activities together to produce a greater impact (Graham, 2006). Classroom-based teaching can allow learners to focus on consolidating their core skills and knowledge. Online learning resources and activities can ensure that learners can revise their work, discuss with their peers in online discussion and be involved in any quizzes or tutorials that can be rehearsed several times outside the classroom. The role of the tutor is crucial in the development in the blended learning. The tutor is a teacher in the classroom, the motivator in both the online and classroom environment and an advisor on the online forum and learning activities. The research work conducted by Chang and Wills (2013) show that there is a 15% improvement on learner's satisfaction and performance of using the blended learning approach than using the classroom teaching approach.

The breakdown of this paper is as follows. Section 2 presents the related work and literature to e-learning. While acknowledging there is a need to improve the delivery of e-learning for staff training, interactive learning, the combination of online e-learning and face-to-face staff training, is proposed to be a better alternative than adopting e-learning alone. Section 3 presents how interactive learning can be conducted for industry and academia with five case studies to support. Section 4 sums up the paper with the plan for future work.

2. Related work

This section describes the related work to e-learning review. This e-learning review consists of seven key areas that are presented as follows.

1)Emerging technologies: e-learning is considered as an emerging technology that makes impact on the workforce.

2)Continuing professional development (CPD): e-learning is used in continuous professional development, of which staff training and executive education are principal components.

3)The impacts on training: e-learning brings new concepts and implementations for training.

4)Effective team management and motivation: the purpose of training is to improve e-learning implementations, in which effective team management and motivation are important factors.

5)Factors for using e-learning technology in learning: Bate's model and Alexander's model of e-learning are used to explain this. An industrial example is described to demonstrate both models.

6)Advantages and disadvantages of e-learning: The advantages and disadvantages of e-learning over traditional learning are described to highlight e-learning's strengths and weaknesses.

7)Interactive learning: both face-to-face learning and e-learning have their strengths and weaknesses. This leads to the proposal to combine both face-to-face learning and e-learning with their positive effects on the employees and the organizations. The difference between interactive and blended learning is that interactive learning is focused on the dynamic interactions with the learners. Teaching can be tailored to different needs and different groups. Learners progress can be checked and monitored (Sloman, 2001, Lundvall, 2010, Chang, 2003 and Chang, 2015). Blended learning is more focused on the mechanism and a variety of learning techniques that learning should be taken place (Garrison and Kanuka, 2004 and Graham, 2006).

2.1. Emerging technologies

Emerging technologies are technologies that create new industries and transform existing ones (Day, Schoemaker, & Gunther, 2004). E-learning is an emerging technology that makes impact on the workforce and reshapes the relationship between employees and organizations. This concept has been elaborated by Bell, Lee, and Yeung, (2006), who highlight a set of significant and common challenges to both organizations and employees. These challenges are considered as human resource challenges that are driven by interaction between factors:

- The properties of emerging technologies.
- Changing character of people (employees and customers) and what they are seeking.
- The changing character of organizations and how they are approaching their human capital.

Interactions driving human resource challenges (Day et al., 2004) represents the relationship between emerging technologies, organizations and people. organizations play a central role because organizations should be aware of the impacts due to the changes in people (employees and customers) and emerging technologies. organizations provide training for office-workers, so that they can get familiar with organizations' emerging technologies to improve their efficiency. Thus, people and emerging technologies are linked together through organizations. E-learning can provide assistance for these interactions because it provides rapid communications between colleagues and improves the quality of the work. The process of improving the quality of the staff in order to set a better quality of work is called continuing professional development (CPD).

2.2. Continuing professional development

The Engineering Council (US) defines continuous professional development (CPD) as “The systematic maintenance, improvement and broadening of knowledge and skill, and the development of personal qualities necessary for the execution of professional and technical duties throughout the practitioner's working life” (Friedman & Phillips, 2004). CPD, being essential for the organizations, includes executive education and staff training. Fig. 1 illustrates the concept of CPD.

Lorriman's Windows (1997) explains the three key elements in CPD. First, there must be a mission by each individual for their self-improvement. Each member of staff should understand their key competencies and all learning should maximise the speed to develop these competencies. Secondly, organizations should redefine the role of their managers, so that coaching and developing of staff become a highly important activity. Thirdly, the organizations should provide a learning environment and maximise learning processes. How can we achieve these three elements? Training, especially training by e-learning, is a key solution used by many organizations. Lorriman's theory can be presented in Fig. 1.

2.3. The impacts on training

Sloman (2001) claims the internet has changed the ways we work, including training. The ways that trainers conduct training and the way employees learn have become different because the internet and other technologies can allow the speedy distribution of information, knowledge sharing and self-learning, in which the trainers' role diminishes. However, Sloman (2001) is optimistic that “training may be entering a new age with growing respect for the importance of the function." He further adds that many organizations recognise that ‘people are a source of competitive advantage’, hence training with e-learning becomes more important. A systematic training model has been increasingly accepted in the UK since the late 1960s. Through years of evolution, a common model was adopted, as shown in Fig. 2.

This model divides training into a series of sequential steps and the benefit of this model is to focus on the need to apply a systematic, disciplined approach to each stage in the process. E-learning not only can accelerate the speed in the whole cycle of the model but also can assist in each process of the training. For instance, the software and internet can assist directors to identify training needs for the organizations. Later, trainers can plan and design training with the aid of technologies. During the delivery of training, intranet, software and video- conferencing can assist the learning process. To evaluate training outcomes, online assessments can be used.

2.3.1. McKay's concepts of staff training

McKay (2000) classifies training into two types, either skill-based training or information- based training. In the context of this thesis, staff training means skilled-based training for office-workers and operational staff. She suggests training everyone together causes a problem because staff may end up with different levels of skills either weak or strong, which then results in team ineffectiveness. To solve this problem, one solution is to train different levels of staff with the appropriate methods. This enables the organization to make better investments in staff. This also saves the organization money in the long-term because less training will take place to reach the required standards.

2.4. Effective team management: a factor for effective e-learning implementations

One purpose of staff training is to build up competent teams, which are capable of handling tasks efficiently. Building competent teams improves the quality of work and the quality of team management, thus leading to effective team management, which is essential for the effective e-learning implementations. Lowe (1995) states that managers and all the employees should be continuously able and motivated to acquire new skills, so they can contribute to technology management within the big organizations, where each manager is in charge of at least one project that has several employees working together. The ability to manage the team for project completion, quality work, time management, training and human resource management is known as team management. Effective team management is important in influencing the project's success.

2.4.1. Motivation: a key factor for effective team management

Lowe (1995) and Steers, Mowday, and Shapiro, (2004) both suggest that motivation is a key factor for effective team management. Both relate that the expectation theory is a more recent approach to study motivation. The concept is that for people to be motivated they should perceive this: if they increase their effort at work, this must lead to an enhanced performance that leads to appropriate rewards. In order to achieve this, motivation is a key factor. Osterloh and Frey (2000) elaborate that a good manager should raise the motivation of his team members. They also explain that keeping motivation high and transforming motivation into performance will be a key to successful management.

Freeman and Capper (1999) elaborate that online education at the University of Technology, Sydney (UTS) allows students to increase their motivation and interests in learning. More students feel online education is useful because they enjoy learning due to the increased motivation. Especially for non- English speaking background (NESB) students, they enjoy learning and knowledge sharing with their friends the most.

2.5. Factors for using e-learning technology in learning

From the previous example, increased motivation and interest in learning is a key factor for using technology in learning. Bates (1997) states four main factors to explain this:

1.To improve access to education and training.
2.To improve the quality of learning.
3.To reduce the costs of education.
4.To improve the cost-effectiveness of education.

Bates states that the fourth factor is not the same as the third as he argues that “for the same dollar expenditure learning effectiveness can be increased, or more students can be taught to the same standard for the same level of investment.”

2.5.1. Bates' model of e-learning

Bates (1995) has taken a wide range of factors into consideration and summarises the following factors that influence effective implementations as the model of e-learning, the ACTIONS model:

Access.
Costs.
Teaching functions.
Interaction and user-friendliness.
Organisational issues.
Novelty.
Speed of course development/adaptation.

In terms of ‘Access’, all staff should have the easy access to the e-learning system. In terms of

'Costs', the e-learning system should be cost-effective. The e-learning system should also provide ‘Teaching functions' for learning and training. For a lively e-learning system, ‘Interaction and user-friendliness' are key elements. Furthermore, the e-learning system should address ‘Organizational issues' by supporting organizations' goals and improving knowledge and skills of the staff. The e-learning system needs ‘Novelty', the innovation that makes it more lively and creative. Lastly, the ‘Speed of course development and adaptation' of the e-learning system should be quick and efficient.

To elaborate this model, an industrial example in Section 3.2 will be used to demonstrate how these factors work. Before introducing this example, the four-level e-learning model is useful to illustrate for the process of learning.

2.5.2. Alexander's four-level model of e-learning

Another e-learning model is illustrated by Alexander's four-level model of e-learning (Alexander and Cosgrove, 1995 and Alexander, 2001). The first level is about online presentation and publishing. A lecturer can put course materials on his subject on the university's intranet. The second level is about online quizzes or assessment. This provides an alternative type of assessment. The third level is about online forums that allow students to provide feedback and the opportunity to discuss online. An example of this is that many students can join online forums, discuss opinions and exchange ideas to make their arguments clearer. Hence, the third level can train students how to express their thoughts and how to present them.

The fourth level is about interactive learning, particularly online role-play simulation. Not only does it combine all the benefits of the first three levels, but also it greatly strengthens knowledge creation and knowledge sharing by face-to-face presentations, face-to-face discussions, online debates and online discussions. Alexander's four-level model of e-learning contains aspects of interactive learning because this model makes use of software, internet and videoconferencing to assist learning, in the presence of lecturers and tutors. Alexander's model can be simplified in Fig. 3:

Bates' model and Alexander's model focus on different aspects of e-learning in which Bates emphasises the factors influencing effective e-learning implementations but Alexander emphasises learning processes and their effects on learners. To illustrate both models are applicable to both industry and academia, five case studies with an effective e-learning implementation, particularly the adoption of interactive learning, will be explained in Section 3.2.

2.5. Advantages and disadvantages for using e-learning technology in learning

So far the definitions of e-learning, models of e-learning and an industrial implementation of e-learning have been discussed. In order to understand e-learning it is important to discuss its advantages and disadvantages in the industrial context, which is summarised in Table 1 and Table 2 (Horton, 2000 and Chang, 2015). Although e-learning is a relatively new concept particularly for staff training, it has several distinct advantages over traditional classroom training.

2.6. Interactive learning

As presented by Table 1 and Table 2, e-learning has their own advantages and disadvantages. The presence of tutors in face-to-face learning is essential to the development of e-learning since tutors can check learners' progress, provide feedback to learners' progress and assignments, motivate learners and help learners overcome difficulties in learning. Tutors should always be available at regular periods to ensure learners progress and feel satisfied about their progress. Hence, adopting e-learning with the presence of tutors in the process of learning can strengthen the advantages and minimizes the disadvantages of adopting e-learning alone. The combination of face-to-face training and e-learning is called interactive learning (Sloman, 2001, Lundvall, 2010, Chang, 2003 and Chang, 2015). The aim is to ensure all learning materials can be delivered online and tutors can provide consultation and feedback to improve learners' progress and their level of competency. The combined effort can allow learners to stay more focused, understand the requirements to meet learning outcomes and work towards the feedback that tutors have provided. Thus, e-learning can be delivered in more structured and organized ways to improve learners' motivation, competency, learning satisfaction.

Other researchers have their own perspective on interactive learning, which include blended learning (Garrison and Kanuka, 2004 and Graham, 2006), collaborative learning (Stahl, 2001; Stahl, Koschmann, & Suthers, 2006) and flexible learning (Freeman & Capper, 1999). Blended learning focuses on the 'types' of learning that make learning effective. In collaborative learning, the emphasis is on the use of technology that makes learning effective (Stahl, 2001 and Stahl et al., 2006). Flexible learning is a vague term because many types of learning are claimed to be "flexible". Interactive learning emphasizes the human interactions during the process of learning, which mainly include knowledge sharing and knowledge transfer. This emphasis can also investigate the effects from the combination of human interactions and the use of technology, especially efficiency after learning or training. That is why the term interactive learning is used in this research.

Interactive learning is an important part of this e-learning research. Before discussing its benefits to organizations, it is necessary to review the contents of interactive learning and how industry might make best use of them. Learning activities for interactive learning is essential for training and learning since the efficiency can be improved (Chang, 2003; Szummer, Kohli, & Hoiem, 2008). Learning activities are co-ordinated actions that exercise basic intellectual skills, thought processes, and analysis techniques. Learning activities can be used to teach, to exercise, and to test knowledge, skills and beliefs (Horton, 2000). A variety of learning activities for interactive learning are summarised in Table 3 and Table 4.

Both Table 3 and Table 4 show a variety of learning methods and summary about how people learn from interactive learning. However, the emphasis and combination of different types of learning can be varied between academia and industry. Even within academia, different universities and different courses may use different varieties and weightage. Similarly, industrial training can adopt some of the suggested methods and can vary between different sectors, courses and type of training. Further discussion will be presented in Section 4.

How to make effective e-learning implementation is also research question. All the learning methods for interactive learning are summarized. There are different types of learning activities for IL. Amongst all these activities, the role-playing scenarios and virtual laboratories are worth mentioning due to the researcher's experience. At the University of Technology, Sydney (UTS), role-playing scenarios were used to assist students' learning that increased the students' learning interests and motivations in learning. In contrast virtual laboratories are practised at the Centre for Applied Research Educational Technology (CARET), where they have developed software for simulation, learning, education and commercialisation. Their work is relevant to the industrial context because CARET is acting as a technical service provider.

2.7. Emerging services

Cloud Computing has been provided as an emerging service for Higher Education, since teaching and learning activities can be conducted in the modern e-learning. Chang and Wills (2013) demonstrate the Education as a Service (EaaS) that has integrated learning and training activities at the University of Greenwich and has reported a 15% increase in the student learning satisfaction. The current emerging services include Massive Open Online Courses (MOOCs), which have been widely adopted by universities in the North America in particular to disseminate training and teaching activities. Their role is to offer learning and teaching to those who either cannot to pay for expensive tuition fees or those who have not been able to take on learning due to commitment from their work. The impacts to the current e-learning community have been phenomenon in a way that a vast population from the developing countries cannot take on the courses offered by the top-tier American universities. They have reported the effective learning to ensure additional resources can be offered to them directly since they cannot afford to do so even in their home countries. This provides incentives to those with poor financial backgrounds the opportunities and motivation to learn. Similarly, those with work and other commitment can broaden their knowledge of horizon and can on learning and training at their own pace. Nazir, Davis, & Harris, (2015) report that MOOCs students have the low completion rate and conclude MOOCs are not suitable way of learning. However, this is not entirely the case. The reason why people take on MOOCs is due to flexibility (Yuan & Powell, 2013). Circumstances such as change of jobs, marriage, births of new children, death of family members, long-term illness and financial pressure can make people suspend their studies for some time. These people should not be taken into the statistics of incompletion rate. Moreover, the majority of the learners take on the modules they prefer due to the flexibility and interest. The problem lies with discipline, commitment they put in and the lack of structured ways of learning.

The case we would argue is that the use of interactive learning can ensure that learners can get engaged with trainers in real time through the videoconferencing technologies, online forum and chats. This can ensure learners get engaged and feel motivated by trainers who can point out students' problems. Students can attempt their assignment online and get feedback from the trainer. The advantages of adopting interactive learning are as follows. First, interactive learning can enhance their learning outputs since students can pay more attention to their work and ensure they can check their progress and meet deadline. Second, the direct feedback from teachers plays an important role since they can receive learning assistance and keep their progress up-to-date. Students' concerns and queries can be answered directly by the tutors. Third, learners are more aware of their own weaknesses, agenda, learning outcome, expectations and progress, which can be discussed with the teachers so that they can both meet their expected outcomes through structured ways of learning. Students' weaknesses can be identified by the tutors who will instruct students how to improve to meet the course requirements and get them ready to submit and present their work in time.

2.8. Issues to be resolved

To further expand the suggestions raised in Section 2.7, there are technical and organizational issues to be resolved. First, the network service needs to be upgraded with optic fibres, large network bandwidth and high quality of service, availability and reliability to ensure that learners can get connected to learning resources easily and efficiently without spending much time and effort to access to the learning resources at any time. Second, more varieties of learning resources should be provided such as the use of apps, dynamic functions and real-time videoconferencing related to web services, so that learners can ensure they can get hands-on experience of learning and receiving feedback in real-time. Blending learning resources with social media can help motivate some learners and allow them to get interpretations in a way that they can understand (Dabbagh & Kitsantas, 2012). Third, the use of peer-to-peer learning can be effectively used in a managed classroom or lab-based training. While using the Leeds Beckett University as an example, students with slower progress can be offered special sessions with not more than four students per session. Students can learn by reading learning online materials and reflecting their progress to the peers and tutor and tutor explain to them for any questions. Students can also learn from their peers when their peers make faster progress. The encouragement from peers can motivate desire for learning. The tutor then plays a central role to provide feedback, motivate learners and stimulate them for the subsequent level of learning more challenging tasks. In this way, the tutor can conduct Level 1–4 of the effective e-learning introduced in Fig. 3 (Alexander and Cosgrove, 1995 and Alexander, 2001).

Organizational issues should also be well reflected and properly managed before problems can be escalated to the higher levels. First, the management buy-in is required to ensure that all plans have been well supported by the senior management. Second, there is resistance to use new technologies and new policies. Ali, Zhou, Miller, and Ieromonachou, (2016) explain ways that lead to IT resistance and suggest recommendations to reduce this risk by involving users with staff training and ensuring they have made progress through techniques such as interactive learning. Different organizations may use e-learning for different purposes. Third, staff training is important for a high percentage of organizations since employees are required to keep their knowledge up-to-date and become familiar in using new services. In fast-paced services such as security for information management, organizations are required to plan ahead. A large scale surveys on security have been conducted with 220 responded out of 400 IT managers and professionals, whereby staff training have consisted 17% of the spending and investment in security (Chang, Ramachandran, Yao, Kuo, & Li, 2016). In their survey results, there are more than 50 respondents replying that their organizations will invest in £1 million and above their upgrading their security equipment, software and services. This is applicable to e-learning that all resources, data and personal details of learners, tutors and sponsors should be safeguarded and protected. Organizations that will invest more in staff training should be aware of upgrading their services and checking all their resources have been secure and protected. Fourth, the four-level model of adopting interactive learning can be adapted from the Alexander's model in Fig. 3, since this model can improve the collaboration between learners themselves and between learners and tutors, apart from the previous evidences (Alexander and Cosgrove, 1995, Alexander, 2001 and Chang, 2015) that the four-level model is easy to implement. Organizations can find it more acceptable to adopt interactive learning and use different varieties in Table 3 and Table 4 according to their own selections, so that MOOCs can be conducted at any time. The emphasis is to apply any knowledge they use at workforce to product greater impacts to organizations rather than revise for examinations.

3. Discussion

Since e-learning, particularly interactive learning, plays an important role in staff development and learning for academia and industry, case studies will be presented to demonstrate the effectiveness for training and teaching. This section presents two major topics for discussion to demonstrate impacts and contributions offered by interactive learning. The first topic is about how to use interactive learning with different types of emphasis and variations for academia and industry. The second major topic is the summary of case studies in selected universities and organizations. The third topic is the discussion about future direction in the adoption of interactive learning.

3.1. How to balance the use of interactive learning techniques for industry and academia

This section describes how to balance the use of interactive learning techniques for industry and academia since the emphasis and orientations can be different. Referring to Table 3, webcasts, presentation sequences and Scavenger hunts are the common grounds for all types of learning, since all the learners should be able to download webcasts and watch them. They will be able to search information they require to know such as the use of Google and any online resources. They need to be able to express their thoughts, learning experience and research findings well. Learners should be able to articulate their work in a way that is acceptable to both industry and academia.

3.1.1. Industry

How interactive learning in Table 3 can be useful to industry is described as follows. Practical skills relevant and effective to the job with better performances are the expected goals for the majority of staff training (Guzzo and Dickson, 1996 and Janssen and Van Yperen, 2004). Hence, there is an emphasis with the practical skill training. For example, when high-tech machineries has been purchased to a manufacturing organization to increase productivity by 20% a day, all the production line staff need to undergone training to ensure that they are proficient in the use of the machinery and feel confident and comfortable to use machineries like expert users to reduce the percentage of errors they have made and improve the productivity. Similarly, staff in banks can perform more accurate audits and more thorough checks with less time and less effort to double check. In another example, developers can learn new languages and apply them more efficiently to their new projects. Developers can utilize or create libraries and functions to make new Application Program Interfaces (APIs), so that outputs can be presented quickly and appeared in a way that users can understand better about the services since APIs can interact between software and hardware more efficiently and directly without executing additional codes. All these examples support that Drilled-and-practice activities, hands-on activities and team design are common and suitable for these types of training. In developer workshops that core programming skills are aimed for improvement due to the running of simulations and experiments, then virtual laboratories and learning games are required to make that happen.

There are also other types of training that involve with knowledge update to allow employees to know about something new or learn something outside their main area of expertise. The main reason is due to the multi-disciplinary nature of the subject and the fast-pace of the area of investigation such as security and privacy, whereby funding has been awarded to interdisciplinary research projects (ESRC, 2016). In order to ensure both developers and legal experts understand each other's concerns, training has been provided to achieve mutual understanding. For examples, developers can learn laws, regulations and policies about their businesses and business partners since they can identify the difference between the US, UK and Europe towards privacy and data protection laws. Similarly, lawyers can learn about the impacts of ICT to legal challenges to ensure that both lawyers are equipped with the knowledge about IT and privacy laws. This type of training that is focused on knowledge based discussion without hands-on experience, then brainstorming, case studies and group critiques are essential to allow discussion and interactions between different peers. Role-playing scenarios can help motivate the team morale and ensure all the participants can be engaged in the learning activities.

3.1.2. Academia

Training in academia has been involved with the similar types of training as industry: skill-based learning and knowledge-based learning. Skill-based learning can help employees in academia to equip with the up-to-date skills and ensure they are familiar and confident to perform their tasks more efficiently and accurately. Similarly, knowledge-based training can allow employees to be ready with the latest development and theory on the topics of their interests. However, there is an another type of staff training focused on strengthening employees' research skills, since scientists need to conduct independent and advanced research as if they are experienced researchers (Creswell, 2013 and Bryman and Bell, 2015). According to Creswell (2013), researchers need to learn the mixed method approaches including qualitative and quantitative skills. These skills will involve with data analysis, programming, logical interpretation, presentation, surveys, case studies, interviews and academic writing. In general, research skills will need to adopt guided research and guided analysis as the main method of using interactive learning, with occasional use of brainstorming, case studies, virtual laboratories and hands-on activities to ensure that scientists can be fully independent to identify problems, design hypotheses, set experiments, collect results, interpret results and present what they have done.

3.2. Case studies

Selected five case studies from the academia and industry have been presented to show examples how to balance the use of interactive learning with their impacts.

3.2.1. Royal Bank of Scotland

Royal Bank of Scotland (RBS) introduced e-learning in 1999 and opened a new Training and Communication Network (TCN) to offer new staff training. RBS was reported to save millions of staff training since their employees could learn at any time and at anywhere without the need to book accommodation and travel (Morrison, 2003). Employees were reported to have their learning efficiency, morale and motivation up. However, RBS has undergone a period of downsizing due to their poor performance since Year 2008. According to Business Case Studies (2015), RBS still invests in staff training since it helps their businesses stay competitive. Their employees can attend more training and courses to ensure their skills are up-to-date and have better competency in the use of IT for providing a better quality of services. They have adopted Level 3 and 4 learning to all their staff training to ensure that their trainers can double check their employees are competent with their new skills and employees feel the sense of achievement after completing their training. Although RBS does not use the term interactive learning, their training sessions have the elements of interactive learning since all the employees are actively engaged in the learning process and they need to demonstrate how to make theory into practice. The impacts can be enormous for the organization since all the employees are well-quipped with the skills and knowledge they need to improve their business performance.

3.2.2. SAP and Small and Medium Enterprises (SMEs)

SAP has been used as an effective platform for businesses to provide them agility and the efficiency to complete tasks. Using SAP can allow each employee to work on related projects and understand the work-in-progress in other units. For examples, sales team can know the outputs of their recent products from product development team, number of supplies available each week from their suppliers and the cash flow of their products from all the sales agents and merchandizers. In this way, the use of SAP can interact with colleagues in other departments. SAP has been popular in Small and Medium Enterprises (SMEs) with similar cases since SMEs can effectively communicate their colleagues, suppliers, vendors and merchandizers at the same time. Thus, training is essential for employees to allow them to understand the business concepts and strategies set by SAP. Chang (2013) conducts research on how SMEs use SAP for their businesses and investigates the extents of return and risk in the adopting of SAP. All the SMEs involved have used interactive learning to ensure all the staff members are familiar with the processes, functions, products and transactions involved, particularly when they perform live orders and transactions with the other party. Each employee interacts with other business units and understands the progress of their work while being handled by other units or merchandizers. Interactive learning takes place in the form of teleconferencing to discuss with partners about their sales orders. Other forms of team designs, brainstorming, virtual laboratories and hands-on activities based on Table 3 will be required to make interactive learning as smoothly delivered as possible. It is more popular in SMEs since there is a higher tendency for each employee to get involved in the work outside their units (Delmar, Davidsson, & Gartner, 2003).

3.2.3. University of Cambridge

University of Cambridge has started their e-learning consultancy services dated back in 2001, when the Center of Applied Research and Educational Technology (CARET) has established as well as the Cambridge Programme for Industry (CPI) has offered training courses for industry. Interdisciplinary services have been set up to offer part-time and distance learning courses, improve the quality of teaching and learning, increase the revenue and ensure all learners have the opportunities to use the quality services offered by CARET (Chang, 2015). CARET has become the University's main service provider for education and learning and has produced Sakai based virtual learning environments (VLEs) for students and staff. Students can understand complex concepts in a short period of time since they can learn the principles of natural sciences through watching the videos and simulations which can explain all the processes, ingredients, science principles and results. Students can grasp their level understanding in a shorter period of time and can use the ‘additional time’ to learn other new skills. Interactive learning can accelerate this process since both technology-based learning and trainers can point out the areas they do not do well and focus on the training on areas of weaknesses. This is the same for all industrial attendees since they can practice their new knowledge and rehearse several times. The use of interactive learning can ensure all the learners can identify where their mistakes are, have the opportunities to correct them and rehearse until they can fully grasp the new skill.

3.2.4. University of Greenwich

Chang and Wills (2013) report that the supply chain teaching at the University of Greenwich can be delivered by Cloud Computing, which can be further established into Education as a Service (EaaS) to blend different learning activities together and effectively deliver them to ensure that all students can improve their learning, and satisfaction of the learning experience. EaaS has adopted the interactive learning and has enhanced the qualities for both technologies and trainers. In other words, the technologies can provide more up-to-date information in real-time and trainers have a deep knowledge to explain all types of the live changes. This can motivate students since they can see the real issues in place and explanations associated with them. They have demonstrated the use of supply chain services and report that there is an overall 15% improvement in learning satisfaction. Chang, Walters, and Wills, (2016) then investigate further on the impact of EaaS offered to two focus groups of students receiving their supply chain Cloud lessons through interactive learning over a period of one year. The results show two interesting observations. The first focus group has acknowledged the positive learning experience with an average of 15% improvement on learning satisfaction. The second focus group has commented that the delivery has exceeded their expectations. However, they have set very high expectations for the following years. Realistic goals have to be set, negotiated and agreed for the following delivery. The metrics and data analysis also suggest there is a high consistency among all datasets and a good quality of data. Investigations in 2013 and 2015 have provided the positive feedback that interactive learning has been effective in teaching supply chain Cloud for students.

3.2.5. Leeds Beckett University

Leeds Beckett University has offered MSc in Business Intelligence for postgraduate students to train them to be business or data analysts. Students can learn how to use SAS platform to create report, graphs, charts, workflows, analytics and visualization. They can connect to the Cloud servers and work directly on the Cloud services seamlessly without the need to know the complexity behind the scene. Students can import collected datasets into SAS, which can be saved in the Cloud and then transformed the datasets in a way that can be read, processed and analysed by SAS. Students can present their outputs in data analytics and visualization and feel confident that they get sufficient training as a junior data analyst (Alsufyani & Chang, 2015). Interactive learning has been effectively used to ensure that students can keep their progress up-to-date, their programming and IT skills can be improved on the weekly basis and regular feedback has been given to students to ensure they can revise areas that require their attention. Students find that there is an improvement in their learning outcomes. Learning satisfaction before and after the use of interactive learning has been measured and there is a 20% increase in their learning satisfaction in 2015. Thus, interactive learning has been very well delivered in higher education and training for data analysts.

3.3. Future directions

Future directions with e-learning services for industry and academia are as follows. First, the combined effort from interactive learning and technology-based learning can be managed and delivered more effectively to ensure that the learners' progress can be checked and monitored, so that learners can understand their weaknesses and areas that need to pay more attention. Any technological based learning, without the learners receiving feedback and support, will have less impact to their learning outcome. Second, the rise of Cloud Computing and Emerging Services can modernize the quality of learning to the next level, since learners can have better access to facilities and resources that they can expect to analyse the data and make sense of the data they have collected within seconds and minutes, by the use of analytics, visualization and easy-to-use interactive functions offered to the learners. Although MOOCs are designed for flexible learning, more structured ways to blend with interactive learning and Level 3 and 4 of learning interactions (Alexander and Cosgrove, 1995 and Alexander, 2001) between tutors and learners as shown in Fig. 3. Only when the instructors have established special work relationships with students and have the experience to lead students into Level 3 and 4 of interactive learning, students can demonstrate satisfactory learning satisfactions. Third, interactive learning can be adapted to different types of groups of learners and ensure learners always follow the weekly requirements on time, even by offline and online tutorial work. Learners should ensure they can rehearse a new skill several times until they can master the skill in the absence of tutors, who then guide the learners at the particular check points and ensure learners can acquire the skill through action research and learning by action. In other words, even if there are better facilities and technologies used in learning activities, if tutors do not convey the expectations for learners to follow (such as rehearse new skills) and convey instructions on how to check learners progress to provide feedback as well as learners take initiatives to be engaged in the process of learning, it will not make much difference. This is identical to Level 4 of learning that both learners and tutors are prepared to put in effort for each other and commit to raise their benchmark after each round of learning process. This recommendation is applicable to both industry and academia, although the appropriate emphasis and varieties of interactive learning activities should be adapted.

Additionally, emerging services that can integrate with blended learning and technologies will be recommended, since learners can have a better access to different resources, take responsibilities in their learning, make advantage of technology that can make search of information and presentation of complex concepts much easier and a better access to tutors. Instructors can play a more influential role as advisers to provide guidance rather than coaches to instruct all the times. With the use of emerging services that combines Cloud Computing, Big Data and Internet of Things, complex simulations in biological science, business intelligence, natural science, operations in machineries, software and service-oriented functions can be presented in a way that learners can find it easier to comprehend and acquire in their learning. Learners can repeat the simulations and learning resources such as videos several times until they can grasp the knowledge and they can rehearse as many times as they feel confident and comfortable to apply their new skills to the workforce, or apply their new knowledge for their research and publications. In this way, the use of emerging services can enhance the learning experience and satisfaction for learners and trainers.

4. Conclusion and future work

This paper illustrates a high level review and discussion of e-learning for academia and industry. Related work and literature have been presented to ensure that all types of learning activities can be blended together. Advantages and disadvantages of e-learning have been discussed, including the discussion about interactive learning, which takes the form of self-directed e-learning and the presence of trainers to check the learners' progress. Learning activities and varieties for interactive learning have been presented in Table 3 and Table 4. Better outcomes of learning are expected since interactive learning can ensure learners meet their expected level of competency and receive feedback from trainers to improve learning performance. Interactive learning can blend with emerging services such as MOOCs to help learners stay focused, work towards goals at different stages, receive feedback and encouragement to stay positive.

A variety of methods to conduct interactive learning has been discussed since the appropriate levels of emphasis and varieties are useful for different types of organizations. To demonstrate the effectiveness of interactive learning, five successful examples of interactive learning have been presented. Positive impacts have been reported in RBS, SMEs using SAP, University of Cambridge, University of Greenwich and Leeds Beckett University. Interactive learning can help learners achieve their goals, have improved rates of learning satisfaction and can ensure employees are equipped with the latest skills and knowledge to complete their tasks better and quicker with more efficiency. All detailed descriptions support different emphasis of delivering interactive learning can be adopted for academia and industry. Our future work will include conducting large scale surveys on interactive learning to investigate the extents of positive impacts to different types of organizations and use quantitative analysis to validate our research contributions.

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Stakeholder Involvement in Sustainability Science—A Critical View

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Abstract. Discussions about the opening of science to society have led to the emergence of new fields such as sustainability science and transformative science. At the same time, the megatrend of stakeholder participation reached the academic world and thus scientific research processes. This challenges the way science is conducted and the tools, methods and theories perceived appropriate. Although researchers involve stakeholders, the scientific community still lacks comprehensive theoretical analysis of the practical processes behind their integration – for example what kind of perceptions scientists have about their roles, their objectives, the knowledge to gather, their understanding of science or the science-policy interface. Our paper addresses this research gap by developing four ideal types of stakeholder involvement in science − the technocratic, the functionalist, the neoliberal-rational and the democratic type. In applying the typology, which is based on literature review, interviews and practical experiences, we identify and discuss three major criticisms raised towards stakeholder involvement in science: the legitimacy of stakeholder claims, the question whether bargaining or deliberation are part of the stakeholder involvement process and the question of the autonomy of science. Thus, the typology helps scientists to better understand the major critical questions that stakeholder involvement raises and enables them to position themselves when conducting their research.

Keywords: Sustainability science; Stakeholder involvement typology; Energy transition; Transformative research.

1. Introduction: stakeholder involvement in sustainability science

The involvement of stakeholders into science is an expanding trend in an increasing number of research areas, especially in those that besides their technological dimension touch societal, economic and political interests.[1] Due to the complexity of such fields like i.e. the energy transition,[2] the scientific community felt the need to go beyond conventional scientific methods by incorporating non-academic actors' views and knowledge in their research through stakeholder involvement.[3] The concept that is common in the economic realm (mainly to deal with Corporate Social Responsibility strategies) or the political realm (i.e. in decision-making processes) has thus been integrated into the broader science environment and especially into new scientific fields such as sustainability science [60], [19], [66], [54], [87], [56] and [120], transformative research[4][101], [113], [24] and [22] and transition research [62], [36], [37], [70] and [75]. These new fields incorporate a broad array of concepts like post-normal-science [35], mode-2 science [40], mode-3 science [101] or citizen science

[53] and [31] as well as transdisciplinary [51], [8], [23], [103], [10], [55] and [83] and participatory research strategies [57], [59], [5], [97], [102], [42] and [96].5

In this context, the main objective of stakeholder involvement is to tackle the “complexity, uncertainty, and multiplicity of values” and perceptions on controversial issues such as the energy transition, or mitigation and adaptation to climate change by combining “expert assessments with problem framings of the lay public” ([58]: 181). Lang et al. [67] refer to objectives of stakeholder involvement by saying that sustainability issues need “the constructive input from various communities of knowledge” here described as scientists from different disciplines and non-academic-actors − to include “essential knowledge from all relevant disciplines and actor groups related to the problem” as well as allowing for the incorporation of “goals, norms, and visions”. Particularly the involvement of citizens is linked to discussions on challenging existing epistemologies of science and assessment of knowledge production and knowledge validity ([107]: 116). Welp et al. ([116]: 170) describe stakeholder involvement in science as the “structured communication processes linking scientists with societal actors such as representatives of companies, NGOs, governments and the wider public”, called “science-based stakeholder dialogues”.6 A more pragmatic branch of stakeholder participation engages with the development and implementation of methods and participatory tools intended to support sustainability learning and the transformation of agents through “effective interfaces between knowledge and action” ([50]: 379; [21]: 64).”

This implies that transformative research does not focus on “intrinsic” scientific discussions, but on solving “extrinsic” societal problems ([106]: 180). Weingart and Maasen ([73]: 2) speak of a “democratisation of expertise”, whereas Gibbons ([39]: 161), Nowotny [84] and Nowotny et al. [85] call for the creation of “socially robust knowledge” through combining research capabilities with other institutions, actors and practices which are relevant for the transition to take place. Schneidewind et al. ([100]: 134) add that to generate system, target and transformation knowledge in transformative science, the latter has to integrate “context- and experience knowledge of relevant actors”. Hayn et al. [49] organize stakeholder input on three different levels: on the analytical level, stakeholders bring in system knowledge through their practical experience; on a normative level they add orientation knowledge through their opinions; and on the operative level they incorporate target knowledge and transformation knowledge by working on solutions with their own set of resources and motivations. Glicken [41] divides knowledge into three types: “cognitive, experiential, and value-based”, where cognitive knowledge stems from technical experts, experiential knowledge comes from people sharing their personal experience and value-based knowledge is related to social interests and social values.

Academic literature describes a wide array of opportunities associated with stakeholder involvement – although mostly related to participatory and decision-making processes that concern for example the implementation of GHG mitigation measures [63] and [68], global processes of change [104] or environmental governance [96], [95] and [3]. Stakeholder involvement is said to increase relevance ([105]: 283; [51]: 125; [4]: 387), legitimacy and credibility ([30]: 228; [17]: 8087; [105]: 283), ownership ([67]; [105]: 283; [3]: 472), effectiveness ([35]: 755) as well as the (social) accountability of research ([116]:171; [40]: 3; [3]: 484ff; [67]; [58]: 182).

However, criticism can also be found in the literature, mostly concerning the validity and credibility of scientific results established through stakeholder involvement ([123]: 4). Concerns relate to co-design – the involvement of stakeholders in the definition of research questions and designs ([101]: 121ff) – and the co-generation or co-production of knowledge – i.e. the integration of societal actors’ bodies of knowledge into the actual research process and related scientific findings—([101]: 316; [89]: 269). Pohl et al. ([89]: 271f) identify three major challenges of this co-production of knowledge: the challenge of power, the challenge of integration and the challenge of sustainability. Related to this, some fear that certain kinds of stakeholder involvement might as well threaten the autonomy of science ([106]; [13]: 201; [26]: 14). Brandt et al. ([14]: 7), who define five challenges7 of transdisciplinary research projects, criticize that currently there is “no clear set of tools required for different process phases or integration of different types of knowledge” as well as little “practitioner empowerment”.

Since participatory or decision-making processes – i.e. labelled as "policy dialogues" by Welp et al. [116]: 172f) – typically do not concentrate on the generation of knowledge, we explicitly do not follow these concepts in this article.8 We instead follow the distinction between research processes that aim at improving knowledge and evidence and decision-making or management processes as proposed by Mackinson et al. ([74]: 19). While we relate to the approach of Renn and Schweizer ([95]: 176ff), who developed six concepts of stakeholder and public involvement in risk governance based on "philosophies of participation and collective decision making", we in contrast look at the way stakeholder dialogues between science and society are understood by scientists. This perspective, that we find important for carrying out scientific work with stakeholders, is so far underrepresented in the peer-reviewed literature.

In this paper, we establish a typology of scientific perspectives on stakeholder involvement. Section 2 will briefly outline the methodology behind the typology whereas Section 3 will describe the different ideal types we derive. Section 4 shows an example by applying the typology to the field of energy transition research. In Section 5, we use our typology to analyze and systematize the critique with regard to stakeholder involvement by deriving three continua that enable scientists to position themselves. We conclude by pointing out the critical choices for scientists that arise from this analysis in Section 6.

2. Methodology

Depending on the perspective one takes, stakeholder involvement practices and the difficulties and critical choices they entail, differ substantially. In order to show this, we establish a typology of ideal types of scientific perspectives on stakeholder involvement. Though in practice there might only be hybrid forms, the development of ideal types has a long tradition in sociological studies. They serve as a research heuristic that stresses and exaggerates distinctive characteristics of a group of cases to disentangle different categories ([61]: 83).

In order to develop our types of stakeholder involvement in science, we apply five criteria of differentiation:

1 Role of the scientist: The perception on which role the scientist should take (and in relation to that also the stakeholder) differs widely. This also relates to the question of the autonomy of science (see for example [116]: 180).9

2 Objectives: The reasons why a scientist would want to work with stakeholders are diverse—ranging from increasing impact on real world issues to getting insider information or increasing legitimacy (see for example [95]: 176).10

3 Kind of knowledge: Scientists seek to gather different kinds of knowledge when involving stakeholders. Based on other differentiations such as cognitive, experimental and political knowledge ([41]: 301f) or system, orientation as well as target- and transformation knowledge ([101]: 42ff, 69ff), we structure the kinds of knowledge that scientists can integrate into their research along the range of pure data, information, assessments and normative values.11

4 Understanding of science: Scientists have different understandings of good or appropriate science including not only tools and methods, but also epistemic and philosophical questions ([114]: 53ff). Is science a detached system dealing with self-referential questions or does science serve societal needs? Can science be neutral and objective or does it mirror societal developments and conflicts?

5 Science-policy interface: The role and impact scientists have – or expect to have – on political decision-making, and hence their perceptions of the societal responsibility of science, strongly imply how stakeholders are involved in the research process.

We use the above mentioned criteria to derive a typology based on literature and practical experiences with stakeholder dialogues in climate change and energy transition research.14 The latter stem from our own work12 and from interviews with practitioners that involve stakeholders in their research projects.13

3. Stakeholder involvement typology for scientists

Sections 3.1–3.4 describe four ideal types of stakeholder involvement in science – the technocratic, the functionalist, the neoliberal-rational and the democratic type. Section 4 applies the typology to the field of energy transition research in order to illustrate the different types with specific examples.

3.1. Technocratic type

The technocratic type's main objective when involving 'expert-stakeholders' ([44]; [117]: 5) is to improve the scientific research process by broadening the extent of available information. The role of the stakeholder is to provide issue-specific, objective and falsifiable information that fits into the classical way science is conducted according to philosophers of science such as Popper [91]. Thus, the technocratic view shares certain important characteristics with the literature on expert interviews ([92]: 118ff).15 If lay people are involved in research processes, it is only indirectly as a source of data ([29]: 293f). They do not provide information themselves – e.g. the interpretation of this data – but lend it to scientists who then use it to extract what they consider is relevant for their research ([29]: 298f, [30]: 227).

The impact of stakeholders on science is thus relatively limited in the sense that stakeholder involvement is expected to feed in additional data and information, but not to define or transform the research question or process. The ontological difference between scientists that play an active part in research, and relatively passive stakeholders involved directly (if experts) or indirectly (if lay people), is greatest in this view. Scientists determine all the elements of the research process autonomously, including the ways in which stakeholders are involved. Consequently, the scientific sovereignty of interpretation, or the primacy of science, is kept throughout the research process.

The kind of knowledge that is to be generated by stakeholder involvement is defined from a purely scientific angle. Thus, research questions are derived from intra-scientific debates and controversies rather than societal needs. Consequently, research questions typically focus on the technological dimension of transformation processes rather than on cultural or institutional problems, which are more closely linked to research on implementation ([99]: 83ff). Stakeholders are involved only on an analytical level, providing data and information rather than assessments and normative evaluations. Moreover, since technocratic research is often based on a linear concept of knowledge transfer [9], it tends to neglect questions of implementation and societal impact like the social robustness of the knowledge it generates. Such a relatively narrow concept of scientifically relevant knowledge is in part due to the understanding of the science–policy interface put forward by the technocratic type. In discussions on scientific consultation in policy or decision-making processes, it is often circumscribed by the idea of "speaking truth to power" ([90]: 10f) and emphasizes ethical neutrality and technical advice. Science and policy-making are conceived of as separate fields that are not intertwined. Rather, scientific findings are expected to inform policy processes and provide the foundation for policy measures. How these findings can become relevant in the sphere of politics is, however, not discussed in this context. From a technocratic perspective, this is a question that is to be addressed by politicians or activists, but of no immediate interest to science.

3.2. Neoliberal-rational type

The neoliberal-rational type understands knowledge as "merely a 'hook' on which interests hang their case" ([93]: 173). He thus acknowledges the existence of interest and power in science-society interfaces and understands stakeholder participation as a tool for both groups to impose their perceptions and interests on each other. Stakeholders – such as lobby groups or individuals advocating for their specific organizational, individual or political interests – try to channel their views directly into the research process and indirectly into a public discourse or the political arena. Furthermore, stakeholders are interested in getting legitimacy for certain positions through the "objectivity"16 often claimed by or attached to science ([110]: 297ff). Scientists on the other hand are understood as conscious about the differing interests and thus are able to use only the knowledge or information they find valid or interesting ([52]: 210). Following this understanding, the neoliberal-rational type's objective to involve stakeholders is to efficiently obtain data or knowledge he needs for further research. Both stakeholder and scientist are aware of the mentioned mechanisms and try to use them for their own purposes. Scientists might also want to channel their results into projects and decision-making processes to ensure impact or application of their research. Another motivation for the neoliberal-rational type of scientist to involve stakeholders is the perception of an increased chance of being funded by public authorities that support stakeholder involvement ([99]: 178).

The kind of knowledge scientists try to derive from stakeholder involvement depends on the specific discipline, task and methods applied. Knowledge is not bound to pure data or information, but can also include system, normative and creation knowledge. The phase where stakeholders are involved is not restricted. They might already be part of the negotiating phase between funding partners and scientists. The science-policy interface is thus seen as a "battlefield" where both groups follow their specific interests and bargain about all possible aspects, i.e defining the research question, methods, wording, boundary conditions for modelling exercises, scenarios, possible take-outs, messages and interpretation of the results and communication. The roles of scientists and stakeholders and their respective influence on the research process are not pre-defined in the neoliberal "bargaining" concept of stakeholder involvement. Although scientists are expected to have a slightly greater impact on the research process, no ontological difference between the two groups of actors is detected (each has their own interest and wants to succeed). In a sense, scientists are themselves stakeholders who have personal agendas ([16]: 10). These ontological foundations relate to basic assumptions of game theory ([81]: 155), where rational individuals seek to maximise their utility defined by individual preferences. The understanding of science in the neoliberal sense relates to more relativistic concepts of science such as e.g. Feyerabend [28]. As there are no general rules which scientific reasoning and methods are appropriate, there is no single "right" way to do science. It depends on the actors' perceptions and constellations.

A characteristic framing of this neoliberal-rational perspective is the notion of "win–win situations" which explicitly acknowledges the win-lose taxonomy in a positive way. In the neoliberal-rational view, this behaviour is not perceived normatively (good or bad) but as "natural" or "rational". This relates to the rational choice paradigm [27] and [20] after which individuals as well as organizations are perceived as rational actors that have fixed preferences and strive for optimal choices with regard to these preferences ([38]: 496; [15]). The group politics approach sees scientific controversies as the result of the pluralist bargaining on the political marketplace by different kinds of actors [76]. Following that perspective, stakeholder involvement is just another arena for actors such as governmental bodies, individual citizens, economic, social and environmental interest groups and different kinds of scientists to carry out the battle of power and authority.

3.3. Functionalist type

The functionalist type is based on an understanding of society as consisting of autonomous social spheres, or systems as introduced by Niklas Luhmann [71] and [65]17 and further developed by a number of scholars with regards to social coordination processes [108], [12], [34], [78] and [79]. It takes a social-constructivist perspective and presumes that modern society is predominantly differentiated into functional subsystems such as the economic, the political, the legal or the science system that are defined by the kind of relevance criteria – or codes – along which the world is observed.

From a functionalist perspective, stakeholder involvement has the objective to irritate the science system with other social perspectives and relevance criteria in order to trigger learning processes that can make science more sensitive for societal problems ([121]: 25, [122]: 333). However, these self-reflective processes can only be induced, but never enforced. Hence, stakeholder involvement is perceived as an opportunity or random generator that may, by chance, change the research process.18 In order to generate occasions of irritation, functionalist scientists attempt to integrate 'representative stakeholders' of different societal logics, e.g. from the economic or political systems or civil society organizations. Stakeholders are typically involved in all stages of the research process in order to increase the probability that change takes place. However, this never guarantees that stakeholders' perspectives are well-reflected and adequately incorporated into the research process.

With regard to the understanding of science, this type suggests that the science system consists of all communication that observes the world through the lens of truth – e.g. if an observation can be regarded as true or false according to certain theories or methods, which in Luhmann's terms would form the contingent 'programme' of the science system. 19 Compared to the other types, the functionalist has a completely different view on the pre-described roles of scientist and stakeholder since he emphasizes communication over actors. He does not care who observes the world, but only looks at how it is observed (whether communication is considered scientific or not). The kind of knowledge that stakeholders provide is always related to their respective mode of observation, i.e. depending on the systemic relevance criteria the stakeholders use.

However, as stakeholders such as politicians, businessmen or civil society activists typically act as 'representatives' of certain social systems, they tend to observe events from a political (power/no power), economic (payments/no payments) or moral (just/unjust) rather than a scientific perspective (true/false). As such, these observations are merely 'noise' to science, unspecified communication that does not (yet) make sense in scientific terms. As science generates 'order' from stakeholders' 'noise' by transforming stakeholders' statements into a scientific kind of information, substantial characteristics of their original meaning might get lost. Consequently, a functionalist attaches relatively low legitimacy to the original stakeholder input. It is this tension between irritation potential and scientific re-interpretation that describes the opportunities and limitations that stakeholder involvement generates from a functionalist perspective. In the strict sense, the science–policy interface does not exist from this perspective, since science and politics generate meaning in very different and incommensurable ways. There can be no easy, immediate and substantial exchange or coordination across these different systems, but coordination can be achieved indirectly and probabilistically. Stakeholder involvement is a tool to enhance the probability that self-reflective processes are triggered, especially if they follow a so-called "irritation design" ([78]: 15f, [79]: 24) that takes into account the social, temporal and factual dimensions of system-specific meaning ([72], [80]: 3f).

For stakeholder involvement, this means that scientists should first consider which kind of actors have the greatest impact on the focal system, be it the science or the political system (social dimension), for example because they provide relevant insider information or are especially affected by the research questions. Second, scientists should think about the way statements need to be framed in order to become relevant or "readable" ([34], [80]: 4) in the focal system—for example by explicitly linking opinions to ethical debates that are well-anchored in scientific or political debates (factual dimension). Third, good timing is essential and needs to take into account the temporal structures of different systems, e.g. the length of review processes in science, election periods in politics, quarterly statements in the economy or rapid changes in societies due to salient events.

3.4. Democratic type

For the democratic type, stakeholder dialogues have the objective to integrate actors in society that are touched by a (complex) transformation or sustainability matters ([112]: 232ff; [101]: 314ff) into the research process. Especially through the participation of lay people, science can create legitimacy for itself, thus allowing "for the development of a genuine and effective democratic element in the life of science" ([35]: 740f).

From a democratic viewpoint, extending stakeholder dialogues from experts and scientists to civil society can enhance the quality of the research results ([105]: 283). Concerning the kind of knowledge, instead of only taking data and scientific observations into account, subjective probabilities, science- and knowledge-based opinions and ideas are integrated into the research process. Also, networks and relationships are of great importance. Wiek ([118]: 55) defines this process as collaborative research, where "scientists and local experts not only exchange relevant information but jointly generate (new) knowledge on the basis of their scientific as well as local expertise (joint research)."

By opening all levels of the process to stakeholders, e.g. from the definition of the research questions ("Co-Design",20[101]: 121ff, 182, 211, 314ff) to answering them ("Co-Production"), socially robust knowledge is created ([85]: 166) to achieve a "democratization of expertise" ([73]: 53). Tàbara ([107]: 114) describes a process of knowledge-building that is "co-decided, co-produced and co-validated in partnership, by knowledge holders in different social-ecological contexts” to allow for social learning that can “meet the pressing challenge of sustainability” ([21]: 62).

Besides the impact on the way science as such is conducted, the democratic type also looks at the political implications of stakeholder involvement in science. He argues that stakeholder dialogues are used to improve scientists' policy recommendations and make them more relevant since they reflect a broader range of interests from different stakeholder groups in society.21 Hence, stakeholder involvement is seen as a means to improve the interconnection and exchange processes between science and politics, alas the science–policy interface. Through this transdisciplinary approach [118], [25] and [67] stakeholder dialogues can help bridge the gap between science and society and allow science to adapt to modern complexity [9].

To be able to fully make use of this instrument, scientists have to approach stakeholders at eye level ([105]: 283), fostering a dialogue that reflects on their own and on stakeholder’s roles. Relating to Habermas’ discourse ethics, the democratic type believes that true and valid communication can be achieved if certain rules are adhered to in a dialogue: actors should for example have free access and participate with equal rights implying a power neutrality through the “absence of coercion” ([46]: 31) and avoid strategic communication by disclosing their intentions ([64]: 169). If this is practiced, the “force of the better argument” can be dominant ([45]: 198).

The role of the scientist is to facilitate and moderate the dialogue, bringing together different stakeholders from politics, business, research and civil society in an open arena (relating to the concept of the transition arena of Rotmans [98] and Loorbach [69]. Scientists have to translate the beliefs and languages of the different ‘systems’ while at the same time creating trust and ownership for the research process.22 The sense of ownership can foster stakeholders' engagement in the process and increase the chance that research results are taken into account by policymakers. The established cooperation of stakeholders and scientists enables the researcher to follow the implementation of the scientific results and at the same time strengthens the acceptance of political measures in society ([105]: 283). Through their active involvement, stakeholders are not merely seen as an object of science.

Stakeholders on the other hand can influence and shape the research process through their engagement (or through other forms of (non)-participation: manipulation, therapy, informing, consultation, placation, partnership, delegation and citizen control (see Arnsteins’s Ladder [2]). Consequently, they play an active role and are typically involved in all stages of the research process—from the definition of the research question to the actual implementation of the scientific findings and the derived policy recommendations. This underlines the idea that the democratic type understands science as a tool to support transformation in society and to ensure representation of all people touched by it. 23

4. Energy transition research through the lens of the typology

The European Union’s research funding programme Horizon 202024 provides a useful framework to explore the different types we discuss here, to understand their implications and to illustrate the main controversies arising from each of them when dealing with complex transformations such as the energy transition in Europe. The implementation of the societal or political goals to reduce GHG emissions and increase the share of renewables in energy production in the near future demands scientific research on a large number of technological issues (e.g. smart grids, energy storage or energy efficiency in buildings) as well as ‘sociological’ issues such as behavioral changes in consumption or mobility that require social acceptance for their success. We briefly describe stakeholder involvement strategies in research processes that deal with the transition towards a low-carbon society in Table 1.

The next section presents an outline of the major critical arguments concerning stakeholder involvement in scientific processes and applies the typology to these arguments.

5. Discussion

This paper aims at a better understanding of the critique raised against stakeholder involvement in science. Following debates in science and society, we identify three major critical topics: First, the question of the legitimacy of stakeholders' claims as input for scientific purposes. Second, there is the issue of communication processes that can be perceived as ranging from pure bargaining to deliberation addressing the science-policy interface. Related to this is the more encompassing question of the challenges stakeholder involvement might pose for the autonomy of science. Using our typology as a heuristic tool, we systematize the critical arguments on three respective continua (Fig. 1), showing the implications the different types have for stakeholder involvement in science.

The critique is most strongly directed against the types that are located at one of the ends of the respective continua and, accordingly, it is often issued from a perspective located at the opposite end of that continuum. The legitimacy of claims differs most strongly from the perspectives of the technocratic and the democratic type. When it comes to the question of bargaining vs. deliberation, the neoliberal-rational and the democratic type represent the most divergent perspectives. Concerning the autonomy of science, the critique stems from a rather technocratic or functionalist understanding of science and it is especially directed against the democratic and neoliberal-rational type.

5.1. Legitimacy of claims

When analysing scientific literature and our interviews, we find that one of the most contested problems is the scientific legitimacy of stakeholder input in the research process. The perception of the knowledge that is created through stakeholder involvement in scientific research processes is broadly discussed. How much of the knowledge offered by the stakeholder is relevant and thus can be used by the scientist (to answer the research questions)—as data, as opinions, as information? How strong does the scientist distance himself or herself from the claims. ranging from acknowledging all input as honest to looking through the "objective" lens of science?

On a practical level, the difficulty to differentiate between strategic communication and biased information by stakeholders is a major challenge for scientists. But not only stakeholders might use strategic communication. Funding organizations or researchers may also emphasize "win-win" situations when they want to persuade stakeholders to participate even if their main motivation is the democratization of scientific processes. Another critical point discussed in the literature is whether the opening of scientific processes to non-academic actors might threaten scientific sovereignty of interpretation by challenging intra-disciplinary criteria of knowledge production ([115]: 135).

On a theoretical level, criticism of the position that scientific knowledge can be described as 'pure' or objectively true has been formulated from different angles in the social sciences for a long time. To mention just a few examples, Foucault retraces the co-constitutive relation between knowledge and power ([33]: 27). Feyerabend argues that there can be no universal or definitive criteria for scientific methods or theories and that scientific claims are just as valid or invalid as claims from other spheres such as antique mythology ([28]: 21, 55ff, 249ff). Constructivist scholars highlight the social embeddedness and observer-dependency of all knowledge [7] and [111]. Consequently, the criteria, theories or methodologies which define "valid scientific knowledge" are dependent on the scientific sub-discipline ([106]: 184). Relating this to stakeholder involvement, the way claims are treated is dependent on the researcher's understanding of science.

We refer to the critical trade-offs that arise in such situations as legitimacy of stakeholder claims, describing the kind of stakeholder knowledge that the scientist uses during the research process and how it is used. The continuum reaches from low legitimacy, seeing stakeholder claims as mere noise in the Luhmanian sense, to considering all claims to be honest and true (high legitimacy). Adding to the kind of knowledge, the continuum thus also describes how strongly scientists distance themselves from stakeholder input.

Applying the four different ideal types to this continuum can help to better understand the critique. The functionalist type stands at the far low end, seeing all claims as unspecified 'noise' that is "senseless" unless transformed to the code of the science system. The technocratic scientist believes in the objectivity of science and thus expects stakeholders to provide only data (via lay-people) and technical information (via experts). The neoliberal-rational type is characterized by a high legitimacy of claims since following the logic of mathematicians like Nash, all players know the rules and act in their best interest. All statements are interest-driven and equally valid (or invalid) and thus interests are brought into the research process via inclusion of stakeholder knowledge. The democratic type sees all stakeholder claims or input as honest communication and takes them seriously in the research process. He thus takes into account data, information, science- and knowledge-based opinions, ideas, subjective probabilities, networks and values. Following Habermas' theory of discourse ethics, in a perfect speaking situation, there is no strategic communication ([45]; [64]: 169).

Considering the critique that stakeholder involvement (or the opening of scientific processes to non-academic actors) might pose a threat to scientific sovereignty of interpretation by integrating ‘un-scientific’ kinds of knowledge and challenging intra-disciplinary criteria of knowledge production, the technocrat and the functionalist would agree, whereas the democratic and the neoliberal-rational type believe that stakeholder involvement enhances scientific results. According to the democratic view, involving stakeholders into the research processes can help to expand the perspective of “mainstream science” by incorporating the context-specific knowledge and value judgements of those affected by the research. Also, creating solution-oriented knowledge is considered a goal ([67]: 29f). In the case of the neoliberal-rational type, equally legitimate interest would positively contribute to the research process.

5.2. Bargaining vs. deliberation

Another major criticism of stakeholder involvement in science relates to the question of interest-driven vs. deliberative stakeholder communication. How much convergence or divergence exits with regard to “operational codes of science and politics” ([52]: 207)? There is a mismatch between the positive notion of including the affected and concerned into the former “isolated” scientific research process and the perception of stakeholder involvement as another means to channel specific economic or political interests into research results. The latter is discussed as hampering the “neutrality” of research. Framed differently, this critique addresses the science-policy interface and thus the question whether stakeholder involvement supports a democratization process in science or allows for implicit or explicit lobbying of powerful actors in another societal area.

Even if scientists are perceived as conscious concerning the material interest stakeholders have, they have to rely on their input in the research process (knowledge mismatch). Stakeholder dialogues mostly involve different kinds of actors—ranging from affected citizens to politicians, administration, NGOs, companies, consultancies and lobby organizations. Actors need time and resources to participate, as well as a strong motivation/interest. As Olson [86] has shown, interest groups in democratic societies have very asymmetric chances of organizing themselves and voicing their values, interests and concerns. Especially large and dispersed groups such as citizens, tax payers or consumers are often unable to form interest groups that match the well-organized interests in society of e.g. economic branches ([109]: 737ff). Generally, stakeholder dialogues in science do not involve political decision-making, thus we do not further elaborate on possible motives in that field, but make one point: influencing the public discourse by labeling and enriching and thus legitimizing specific interest-related positions with the “neutrality” and “objectivity” attributed to science could be a motivation for stakeholders to participate.

All this said, the selection bias (concerning who is able and who is willing to take part in a stakeholder dialogue and how scientists choose stakeholders) is a main criticism towards stakeholder involvement in science. On a more general level, this leads to the question whether stakeholder input is understood as part of a deliberative democracy or as part of the bargaining power play of politics.

Depending on the type of stakeholder involvement in science, the views on this critique differ strongly. On the bargaining side, the neoliberal-rational type sees the science-policy interface as a “battlefield” where all actors bargain for their interest [81]. Stakeholders can be lobby groups/individuals who try to channel their interests into the research process and indirectly into the political arena. On the other hand, the scientist tries to influence political decisions. Thus, although the neoliberal-rational type understands the process as determined by interest and power, he does not perceive it as a threat or danger to science. The functionalist type though is indifferent to both bargaining and deliberation since he sees no overlap of the political and the science system. Scientific findings might become relevant for politicians if they trigger reflection in the political system through irritation, but that happens only by chance. The technocratic type is slightly closer to deliberation than the functionalist, believing that ‘explaining’ the world instead of convincing political actors is the right way. This bears the underlying idea that science is objective and scientists ‘speak truth to power’ ([90]: 10f).

The democratic type, following Meadowcroft’s [77] idea of group-based deliberation, lies at the deliberative side of the continuum. Here, the scientist aims at the “democratization of expertise” ([74]: 53) and wants people/groups touched by a transition (or the energy transition) to be represented in the research process as well as science to support the (energy) transition. The involvement of citizen-stakeholders might remedy the influence on scientific results by powerful and well-organized interest groups in society. Another aim is to improve interconnection and exchange processes between science and politics. The democratic type understands stakeholder involvement as a way to increase relevance, legitimacy and fairness when certain standards are met. From a more pragmatic view, the so-called democratization of science may decrease the quality of research results. Following our typology, the technocratic and the functionalist type would argue that political goals (e.g. taking binding decisions according to opinions, preferences or value judgements based on voting) can not be transferred into the scientific realm without fundamentally changing the nature of science. The technocratic type would fear that scientific standards are softened, the functionalist would regard such a tendency as a creeping process of de-differentiation or re-programming by which non-scientific criteria such as social relevance substitute or modify the originally scientific criteria of true and false.

5.3. Autonomy of science

When designing stakeholder involvement, the question of the integration of stakeholders in the research process arises. On a meta-level, this can be summarized as a question of the autonomy or primacy of science.25 Should stakeholders already be included in the definition of the research questions and design process or is it enough to integrate their knowledge later? Literature on stakeholder involvement in science shows that important questions regarding this issue are still far from being answered ([82]: 12; [47]: 132; [67]: 35ff). How can the relation of scientific and non-scientific knowledge be described [45]? By which scientific or democratic criteria can different kinds of stakeholder input in the research process be evaluated? Is the evaluation carried out by scientists alone or jointly with the stakeholders? What is the role of the stakeholders: are they supposed to provide insights and perspectives that can lighten up the blind spots of science, or are they actually doing science themselves?

In this context, stakeholder involvement concepts are criticized for their understanding of science and the science-society relationship they entail ([106]: 180; [114]: 99). With regard to ‘transformative science’ [101], Strohschneider ([106]: 184) identifies four central motives that might lead to the decline of scientific autonomy and pluralism. The most challenging ones are ‘solutionism’ and ‘de-differentiation’. The term ‘solutionism’ describes the framing of research topics as practical problems that scientists try to solve. Strohschneider argues that a solutionist concept of science, which privileges relevant findings over more indirect effects of science (such as basic/foundational research) and questions on design and societal impact over understanding, is reductionist. De-differentiation means that the sphere of science is no longer regarded as an autonomous societal arena that defines its own standards and categories such as the constitution of scientific knowledge or the choice of research topics. Rather, there is a tendency to equate scientific problems with problems of immediate social relevance. According to Strohschneider, this solutionist understanding of science in which epistemic problems are only considered scientifically legitimate if they can be labelled as societal problems ([106]: 183), poses a threat to the autonomy of science.

The typology shows that this critique applies most strongly to the neoliberal-rational and democratic type that show a low differentiation of scientists and stakeholders (left end of the continuum) and thus low autonomy of science. In the tradition of Feyerabend [28], the understanding of science as a separate arena of society with distinct and clear criteria of valid knowledge production, as defended by Strohschneider [106], is no longer taken for granted. Consequently, the roles of scientists and stakeholders barely differ, and stakeholders have a much higher impact on research.

The neoliberal-rational type which relates to the ontological foundation of game theory [81] sees no divergence between stakeholder and scientist since they both act as rational utility-maximizers. The posed research questions thus do not only depend on epistemic interest, but also on the possibility to get research funding or to further one‘s material interests through research. Though on different, more morally oriented grounds, the democratic type rejects a differentiation between stakeholders and scientists and opts for integrating everyone affected as extensively as possible – from the definition of the research question to the structuring of the research ([51]: 125; [105]: 283). The research questions are not limited to epistemic interest but aim at offering solutions for socially relevant problems.

In contrast, both in terms of the involvement of stakeholders in the research process and the underlying understanding of science, the technocratic type seems to be closest to a classic understanding of science in the tradition of Popper [91] that sees a strong qualitative difference between trained scholars and lay stakeholders. The scientist is in charge of the research design and merely consults stakeholders if he or she feels they can provide useful data or information. The research questions typically deal with intra-scientific debates rather than societal needs. The functionalist type also perceives science as an autonomous arena with distinct relevance criteria that differ substantially from those of the economic or the political system. As in these more classic perspectives on the science-society relationship the motives of ‘solutionism’ and ‘de-differentiation’ are rejected, Strohschneider’s critique does not apply to them.

6. Conclusion

There is an increasing trend of including stakeholders in research on sustainability or transformations like the energy transition. Though frequently used, little theoretical reflection on the underlying concepts of stakeholder involvement in science by the practitioners themselves exists so far. With the typology described here, this paper tries to fill this research gap by offering a heuristic, self-positioning and decision-making tool for stakeholder involvement in scientific research processes. The differentiation of four different ideal types linked to the critique that has been voiced among practitioners and in the academic literature can help scientists to better understand the different concepts of stakeholder involvement and potential pitfalls in designing it. By identifying and analysing three major critical topics with our typology – the legitimacy of claims, the idea of bargaining versus deliberation and the autonomy of science – we reveal critical choices that every scientist involving stakeholders should be aware of, thus giving an impulse for further discussion in this field. Our analysis also shows that – even though in literature it is often framed in the notion of the “democratic type” – there is no singular concept of stakeholder involvement. With the application of our typology to the energy transition, we emphasize one of the major fields where stakeholder involvement is strongly used and at the same time link the practical and the theoretical level in the discussion.

The tool presented here can only be an aid of orientation concerning the major critical points of stakeholder involvement addressed in this paper. The complexity of societal transitions will keep challenging science—especially the question of its autonomy among claims of democratization and vested interests and its input between scientific and non-scientific knowledge.

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EvoText: A New Tool for Analyzing the Biological Sciences

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Abstract. We introduce here evoText, a new tool for automated analysis of the literature in the biological sciences. evoText contains a database of hundreds of thousands of journal articles and an array of analysis tools for generating quantitative data on the nature and history of life science, especially ecology and evolutionary biology. This article describes the features of evoText, presents a variety of examples of the kinds of analyses that evoText can run, and offers a brief tutorial describing how to use it.

Keywords: Text analysis; Digital humanities; Software; Philosophy of science; Philosophy of biology; History of science; History of biology; Biology.

1. Introduction

What is the nature of science and how has it changed over the past 150 years? What drives scientific change, and what accounts for when and why scientists give up cherished views to adopt new ones? There are a number of distinct approaches to answering questions of this kind, representing divergent ways of understanding the nature and status of particular sciences—or of science in general—arising from a variety of disciplines. There are traditional philosophical approaches, focusing on the conceptual structure of science, asking questions like what is a scientific explanation? or what distinguishes science from pseudoscience? There are sociological approaches, focusing on questions like what do scientists actually do on a day-to-day basis? and why do scientists make the decisions that they do (is it in pursuit of truth, power, status)? There are also historical approaches, detailing moments in the history of a science to say what happened and why. Each approach has its benefits and limitations. One trade-off between them pits specificity or depth against generality or breadth. Traditional historical approaches, as well as the philosophy of particular sciences (biology, physics, etc.), tend to be narrow in focus, detailing a specific moment within a particular scientific discipline, while general philosophy of science often sacrifices specificity for broader application. It is understandable that many approaches opt for depth rather than breadth: attempting breadth generally brings about superficiality and bias. It is difficult to be representative when confronted with a body of information too large to absorb, and safer to be comprehensive in a small area.

With the digitization of the scientific literature, a new way of engaging with science is beginning to emerge. We, for the first time, have access to digital repositories of hundreds of millions of pages of scientific, philosophical, and historical text. These repositories open up opportunities to examine, on a broad scale, how science happens. Unfortunately, however, there is a lack of tools for studying this corpus of texts in a rigorous way that would produce statistically significant results. Much of the focus has been on producing ways of discovering articles (e.g., Google Scholar) or digitizing material that has not previously been available (e.g., the Darwin Online project (van Whye, 2002) or the Einstein Papers Project (2014)).

We introduce here a powerful new tool, evoText, which provides a window into science that will allow for broad scale quantitative study of the science journal literature—it is thus a way of retaining breadth without becoming superficial or subject to the biases inherent in manually working through large sets of texts. By combining algorithms developed in the sciences and digital humanities with a corpus of science journals, evoText will allow for the study of science in a way not heretofore possible.

In this article, we show what makes evoText distinct from other digital tools, and we describe the corpus of journal articles it contains and the analysis tools it offers. We then offer an example of the kinds of analyses that evoText can support.

2. The unique nature of evoText

There are many high-quality software packages for analyzing texts, such as SEASR (Ashton, 2011), TAPOR Tools (Rockwell, 2006), MONK (Kumar, 2009), Google's N-gram Viewer (Brants and Franz, 2006 and Michel et al., 2011), and JSTOR's Data for Research (Burns et al., 2009). Each, however, is inappropriate for the problems that evoText aims to solve. Several packages—including TAPOR Tools and MONK—require that the user upload texts into the system, making analysis of the size of corpus deployed in evoText (hundreds of thousands to millions of documents) impracticable. Some, such as MONK, require for full capability that the texts be marked up manually in a format like TEI (Ide and Véronis, 1995), which, again, is infeasible for analysis of a corpus as large as ours. Other tools, such as Google's N-gram Viewer and JSTOR's Data for Research, have large corpora of text against which they are deployed, but they have significant limitations. JSTOR's corpus is limited to the journals they happen to have agreements with and is thus unlikely to be a representative sample of all journals. And Google's N-gram Viewer contains only the corpus that the Google Books Project has thus far digitized, limiting the inferences one can make about cultural dynamics from its analysis (Pechenick, Danforth, & Dodds, 2015). No general-purpose tool presently available is optimized for journal articles. The challenges presented by the analysis of millions of small texts (as is the case with journal articles) rather than a much smaller number of considerably larger texts (like books) are unique and significant. Finally, some current programs (such as SEASR or TAPOR Tools) require the user to chain together many smaller analysis steps to perform common data analyses, presenting a usability challenge.

evoText resolves each of these issues. Its corpus contains a vast collection of journal articles, thus not requiring users to upload these texts themselves. Its analysis tools work against plain text, allowing us to add substantial numbers of texts without costly processing or encoding time, and to include specific features to clean OCR text. These qualities, in addition a to user-friendly website, allow users to perform common analyses with a few clicks.

The software powering evoText, called RLetters, is available under the MIT License (Open Source) at http://123.233.119.36:80/rwt/119/https/M7VYI4DWMIYGG55N/rletters/rletters. While evoText will have a corpus of articles curated by us, if a user wishes to analyze a different corpus of articles, they are free to use the RLetters software to accomplish this (Pence, 2016).

3. The journal database

Our journal database currently contains open access content from a variety of PLoS journals, and closed access content obtained via text mining agreements as well as partnerships with Nature Publishing Group, Elsevier, and JSTOR. At press time we have more than 400,000 journal articles, but are adding articles on an ongoing basis. The corpus focuses on journals related to evolutionary biology, but is not limited to this topic. Our goal is to be as complete as possible in our collection of evolutionary biology journals, but to include a large array of articles in neighboring disciplines. For example, from JSTOR we include the entire array of journals in their “Ecology and Evolutionary Biology” category as well as “General Science.” As the project progresses, we will continue to broaden the corpus.

We are sensitive to the worry that housing the content in this way constitutes, in essence, yet another example of “data siloing” in the digital humanities—the construction of another closed collection of data to which only the evoText maintainers will have full access. At the moment, however, there exists no alternative if one desires to mine more than open-access or public-domain texts. JSTOR, for example, has informed us that a solution in which we store the full text of their articles on our own servers is legally infeasible. This is a recognized problem in textual analysis, of course, as those in charge of closed-access data archives like HathiTrust have repeatedly emphasized

(York, 2009). We believe, however, that deciding to analyze only open-access texts is the wrong solution—particularly if publishers can be made to see the demand present for this kind of textual analysis in the scholarly community. We would be glad to work with researchers who would like to negotiate closed-access content agreements similar to our own.

4. The evoText tools

A wide variety of analysis methods are implemented in evoText, and are described here briefly. More detail can be found in Pence (2016), or below in the discussion of our example use of evoText.

Compute Term Frequency. Users can compute term frequency tables for a given dataset, for either single words or multiple-word phrases (n-grams) (modeled after features in Tsukamoto, 2002). These are the most common inputs for other kinds of textual analysis algorithms, meaning that users can easily extract term frequencies and use them to run their own analyses locally if desired.

Co-occurrence and Collocation Analysis. Information may be extracted concerning statistically significant collocations (immediate pairs of words) or co-occurrences (significant connections between words at the sentence, paragraph, section, or article level) (Manning and Schütze, 1999).

Compare Difference Between Datasets. The Craig Zeta algorithm (Burrows, 2006 and Craig and Kinney, 2009) can compute the difference between datasets, showing which words, if found in a random article, would be likely to “mark out” that article as belonging to either set.

Compute Term Network. Users can visualize the network of words occurring in the immediate vicinity of a given focal word of interest, an analysis that is useful for determining which words often “travel together” in the literature (He, 1999).

Extract Proper Names. Proper names (of persons, locations, organizations, and so forth) found in journal articles can be extracted. This analysis can be useful to detect locations of field research, organizational networks, etc. (Manning et al., 2014).

Graph by Publication Date. Users can graph the publication dates of a dataset, which is particularly useful if the dataset contains only those articles that match a complex search.

Export Citations. Lastly, a dataset can be exported in a variety of citation formats to a user's citation manager, including EndNote and BibTeX.

5. An example of an evoText analysis

To show the power of evoText, let's consider an example.1 For the example, we investigated what the word ‘evolutionary’ modifies across journals and across time. We began by determining the ten most frequently occurring ‘evolutionary ___’ bigrams (pairs of words) from the journal Nature during the decade of the 2000s. Starting with the most frequent, they are biology, ecology, history, change, dynamics, processes, time, process, genetics, and theory. See Fig. 1 for a word cloud representing the frequency of these bigrams (and see the Appendix for information about how this figure was generated using evoText).

Given this distribution of bigram frequencies, we might wonder how they came to be. When, for example, did we begin to use ‘evolutionary biology’ at such a high frequency? To examine how these frequencies changed over time, we plotted the frequency of the bigrams (the number of occurrences divided by total number of bigrams), all the way back to the 1870s (see Fig. 2). To reduce clutter, we focused only on the five most frequent bigrams. In this graph, we are able to see how and when these bigrams became as frequent as they now are. Fig. 2 shows some interesting trends. Not unexpectedly, ‘history’ and ‘change’ have remained fairly constant over the history of the journal. From its beginning, with the publication of Darwin's On the Origin of Species (1859), evolution has always been understood as a historical science concerning organic change. The data from Nature confirm these as core elements of our understanding of evolution throughout its history.

The evolutionary biology, ecology, and dynamics bigrams, on the other hand, all take off in frequency around 1950. This timing corresponds with the period following the synthesis of genetics and Darwinism, in which evolution became a discipline of its own, with a society and a dedicated journal. The first annual meeting of the Society for the Study of Evolution occurred in 1946 and the first volume of the society's journal, Evolution, was published the following year (Smocovitis, 1994). Therefore, it makes sense that referring to evolutionary biology and evolutionary ecology would be infrequent before the crystallization of evolutionary biology as an independent discipline, but increasingly common afterward. The term ‘evolutionary dynamics’ takes off around the same point, though it has a slower increase than biology and ecology. Its increase might in part be attributed to it being a more technical term than ‘change’, and it is interesting to note that ‘evolutionary change’ decreases during the same period that ‘evolutionary dynamics’ increases. This may be purely coincidental, but it may also point to a replacement of ‘change’ with ‘dynamics’.

If we were to further investigate this increase in ‘dynamics’, we might wonder whether the journal Nature is representative of broader trends in evolutionary science. A plausible initial hypothesis would be that because of Nature's status as a general science journal, it would be slower to introduce the term and would use it less frequently. As an initial test of this hypothesis, we could compare the frequency of use of ‘evolutionary dynamics’ in Nature with its usage in a more specialized journal like Evolution (measured as the number of articles containing the bigram divided by total number of articles for each year). When we do so, we find that the bigram takes off in roughly the same year in both journals and has a similar pattern of increasing frequency (see Fig. 3). With some allowance for noisy signal, the pattern of use of ‘evolutionary dynamics’ appears to be broadly similar in both journals, suggesting that we are seeing a field-wide change in terminology. Of course, the absolute frequency in Nature is lower by more than an order of magnitude, but this can be attributed to the fact that Nature publishes on a wide array of topics.

6. Conclusion

evoText is a tool for historians, philosophers, scientists, and any others who wish to gain insight into the nature and history of science. It contains a database of hundreds of thousands of articles and supplies tools to run sophisticated algorithms. These algorithms allow researchers to plumb the depths of the sciences, gaining data and insights not heretofore possible.

We hope that you will explore evoText to see how it might shed new light on your research projects. If you have questions about evoText, we encourage you to contact help@evotext.org. The evoText database is currently focused on particular areas of biology (principally ecology and evolutionary biology) as well as general science, though we plan to expand into other areas in the future. Active development continues on evoText—if there are specific subjects, journals, tools, or other features that would be useful to you, please let us know and we will see how we might accommodate your needs.

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Appendix. Generating Fig. 1

Fig. 1 was directly generated using evoText, while Fig. 2 and Fig. 3 used data generated by evoText in conjunction with Microsoft Excel for graphing assistance. Fig. 1 is the most involved, so we offer here a tutorial for how to generate it. To get started using evoText, visit http://123.233.119.36:80/rwt/119/http/P75YPLUFP3YYI3LZPRYG86UH/ and create a user account. Your account will allow for the storage of your personal user data, your datasets (about which more below), and your analysis results.

To begin generating Fig. 1, click the “Start a new analysis” button on your dashboard page. This brings you to a list of the kind of questions you can answer using evoText. For our task, scroll to the bottom and select “What's the frequency of word use within a given set of articles?” You'll now be presented with a page of information about the analysis method you've selected. Click “Start.”

You now need to provide your analysis with some data. For this figure, we want to search in the 2000s decade of Nature. Click “Create another dataset,” and you'll find yourself in evoText's search interface. Building this dataset is easy. Start by clicking “2000–2009” on the right-hand side, under “Filters … Publication Date.” Now you're only seeing results in the list for articles published in the 2000s. Then click “Nature” under “Filters … Journal.” You now have the set of articles that you're interested in (at press time, this was 29,412 journal articles). Save this collection as a dataset by clicking the green “Save” button. Give your dataset a descriptive name (like “Nature 2000s”), and click “Create dataset.” This dataset is permanent, and in the future you will be able to run more analyses on it by selecting “Link an already created dataset” instead of “Create another dataset” in the “Collect data” window.

We have now returned to the “Create data” window, with your newly created and named dataset in the list of “Datasets for this job.” Click “Set Job Options.” This is one of the more complicated analysis tools in all of evoText. To generate our word cloud, set the following options:

- Analyze single words or n-grams? Select “N-grams,” as we are interested in multiple-word phrases.
- Size of phrases to analyze: 2. This specifies that we want the frequency of bigrams (phrases of two words).
- Number of n-grams to analyze: We're interested in the ten most commonly occurring bigrams, so leave the “Return all n-grams” button unchecked and enter 10 into the field.
- Include only n-grams that contain one of the following words (space-separated): Enter ‘evolutionary’ (without quotes), and we will only get information on bigrams that include the word ‘evolutionary’.
- Exclude any words? Select “Most common words (stop words).” This removes a set of uninformative “stop words” (such as ‘the’, ‘and’, ‘a’, ‘of’, and so on) from the frequency list. This feature can also be used to exclude a custom list of words inputted by the user.
- Language of text (for stop word list): English. evoText includes standard stop lists for a variety of languages.
- Stem words? No. This option removes endings from words, making, for example, ‘evolution’ and ‘evolutionary’ analyze as the same word.
- Text block method: By number of blocks. These options control how we will chop the text into pieces before counting up its words, useful for various algorithms in the digital humanities.
- Number of blocks: 1. This allows us to look at all the documents in the dataset in a single block.
- Split blocks across documents: Checked. We want to get one block that includes all the documents in our dataset, not one block per journal article.
- Create a word cloud: Checked.
- Word cloud font and color: Choose as you like! We used the “Vollkorn” font and “Blues” color to generate the word cloud in Fig. 1.
- Show words in the inclusion list in the word cloud? Unchecked. If this box is checked, the word cloud will display ‘evolutionary biology’, ‘evolutionary history’, ‘evolutionary genetics’, etc. Since ‘evolutionary’ is in the inclusion list—the list of words to include, from above—unchecking this box will remove ‘evolutionary’ from each entry, giving us a word cloud containing ‘biology’, ‘history’, ‘genetics’, etc., as appears in Fig. 1.

Click “Start analysis job.” Jobs in evoText are performed in the background, and you will be e-mailed when a job finishes. Some jobs will take seconds, while more computationally intensive ones can take days. Click “Fetch Results” at the top of the screen, and you will be able to watch your job's progress. When it's done, click the green “Download” button and select “Word Cloud (PDF)” to download your word cloud. And we're done!

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