THE USABILITY OF REPOSITORY USER INTERFACES:

AN EVALUATION OF SCOTTISH HIGHER EDUCATION INSTITUTIONAL REPOSITORIES

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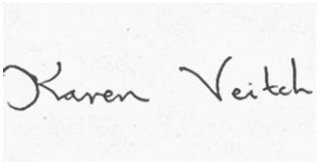

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Abstract

Institutional repositories play an important role in the dissemination and preservation of scholarly research outputs. The last decade has seen substantial growth in the number of repositories and in repository usage within the UK, driven by a range of factors including research council and funder policies. Despite this growth, issues of poor usability have been identified as a significant barrier to user acceptance of and engagement with institutional repositories.

This research aims to contribute towards a better overview and understanding of usability issues in relation to the Scottish higher education institutional repository landscape. To help achieve this, a novel set of domain-specific usability heuristics is developed. It is hoped that this new set of domain-specific heuristics will be a useful tool for repository managers and usability evaluation professionals. This new set of heuristics was used to evaluate the user interfaces of all 18 repositories provided by Scottish higher education institutions (HEIs). It is anticipated that the results of the evaluations will be useful for repository managers, in identifying the priority areas for improvement and thereby enabling time and resources to be focused on resolving these issues.

The results of the evaluations demonstrated that usability issues are a significant presence across the user interfaces of all 18 of the Scottish HEI repositories. While the greatest proportion of the usability issues uncovered were classed as minor, a significant proportion were classed as major (based on Jakob Nielsen's severity ratings system). The greatest number of major usability violations occurred in relation to the provision of web 2.0 features, help and supporting documentation and usage statistics. It was recommended that these three areas should be prioritised for resolution.

In the event that all major usability issues have been resolved, it was recommended that the most frequently occurring minor usability issues should be addressed, relating to flexibility and efficiency of use, browsing options, making objects, actions and options visible, visual design and terminology. Given the significant extent of the usability issues encountered, it is hoped that the present study will prompt renewed attention to the issue of the usability of institutional repositories, as an important factor impacting on user acceptance and engagement.

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Section 1.0 – Introduction

1.1 Research context

Open access repositories originated from the Santa Fe convention of 1999, which provided recommendations to promote interoperability among 'e-print archives' as well as establishing technical mechanisms to support the discoverability of their content (Open Archives Initiative, 2000). The authors of the opening statement of the Santa Fe Convention note that, while the number of e-prints archives at the time of writing was small, 'we anticipate the creation of many more e-print archives in the coming years' (Open Archives Initiative, 2000). Their prediction would prove to be correct.

Within the UK context, the number of repositories registered with the service IRUS-UK has increased from 13 in 2012 to 146 in 2019 (IRUS-UK, 2019). Not all repositories are registered with IRUS-UK. According to the global repository directory OpenDOAR, there are currently 283 repositories in the UK, of which 224 are institutionally-based (as opposed to being aggregating, disciplinary or governmental). Neil Jacobs (2018) describes that the situation in the UK during the decade following the Santa Fe Convention 'was characterised by Jisc [Joint Information Systems Committee] support for universities to establish and enhance a network of institutional repositories'. Moreover, research funders increasingly implemented policies supporting the use of repositories to promote access to research outputs.

The 2014 Research Excellence Framework (REF) was a key factor contributing to continued growth in the UK repository landscape. The policy required the deposit of research articles into repositories and was 'the first national policy to explicitly link public access with research evaluation' (Steele, 2014, p.252). The 2014 REF policy bolstered the role of institutional repositories as important platforms enabling institutions to fulfil their policy and reporting requirements. The ongoing importance of repositories is further reinforced by the developing policy landscape, with the launch of 'Plan S' in September 2018. Supported by cOAlition S, an international consortium of research funders, Plan S requires that 'from 2021, scientific publications that result from research funded by public grants must be published in compliant open access journals or platforms' (Plan S, 2019). Institutional repositories are the key mechanism that UK universities have in place to be able to fulfil the requirements of this new, ambitious policy.

Moreover, repositories have a vital role to play in ensuring the preservation of and continuity of access to scholarly content. The significance of this role for repositories was articulated in the early period of their development by Clifford A. Lynch, in his assertion that:

> At the most basic and fundamental level, an institutional repository is a recognition that the intellectual life and scholarship of our universities will increasingly be represented, documented, and shared in digital form, and that a primary responsibility of our universities is to exercise stewardship over these riches: both to make them available and to preserve them (Lynch, 2003, p.329).

Institutional repositories retain their important role as infrastructure that ensures immediate accessibility to research outputs, as well as preserving these materials over the longer-term. Furthermore, repositories remain significant as a key vehicle for promoting the discoverability of content (Macgregor, 2018). To this end, a range of technical measures can be employed to boost the discoverability of repository content for external search engines such as Google Scholar and aggregators such as CORE (Macgregor, 2018).

However, the rapid growth of IRs within the UK and international context over the last decade has led to problems of inconsistency, lack of interoperability and lack of implementation of measures to boost content discovery. The prevailing situation in which repositories have been developed and implemented locally has led to significant duplication of effort across institutions. Arlitsch and Grant (2018) examined the landscape of institutional repositories and concluded that developments thus far have been overly fragmented. They argue that the library/information profession is 'wasting huge amounts of resources in duplicating shared IR infrastructure' (Arlitsch and Grant, 2018, p.269). The redundancy of effort and wasted resources frustrates the ability of those professionals implementing repositories within their institutions to create usable platforms. Arlitsch and Grant argue that 'repositories are clearly not working very well for users, either on the discovery end or the submission end' (2018, p.271). This echoes the findings of an earlier study by Davis and Connolly in which they found that academic staff thought of IRs as 'islands' (2007, p.16), unique yet isolated resources. Similarly, Karen Calhoun identifies that the major barriers to the success of IRs have been 'a lack of clarity around purpose and focus, weak understandings of community needs and attitudes, scholars' lack of awareness of the repository or its benefits and recruiting content' (2014, p.180). These views resonate with those expressed by Dorothy Salo in her influential article 'Innkeeper at the Roach Motel' (2008), in which she argues that IRs are poorly aligned to user needs.

The disjointed nature of the development of IRs has created a fragmented landscape, embodying variations in function, design and usability. Jacobs describes the scenario in the UK as 'a crowded, potentially confusing and inefficient landscape, though one filled with innovation' (2018). The issues caused by the fragmented nature of the repository landscape's development have been exacerbated by issues of institutional under-resourcing and a lack of attention to the issue of usability

(Tay, 2017). As Macgregor describes, 'many repositories have not undergone development beyond their original establishment and the ongoing maintenance of its scholarly collection' (2018, p.1). Institutional under-resourcing and the related lack of repository development combine to create significant usability issues within the UK repository landscape.

Institutional repositories rely heavily on user engagement for their success. It is hard for academic staff to see the benefit in contributing research outputs to platforms that they themselves find difficult to use. This insight applies to academics in their (often overlooked) role as information seekers as well as depositing authors (McKay, 2007a). Beth St. Jean *et al.* note that much of the existing IR literature used the term 'user' to refer to authors, rather than information seekers and has focussed attention on issues of content recruitment, more than on usability (2011). Yet, as the authors argue, it is crucial to recognise the dual nature of IR users as both authors and information seekers, as these groups are often constituted by the same set of people.

The poor usability of institutional repositories has been identified as one of the main reasons why researchers avoid them (Tay, 2017). Poor user experience has significant negative implications for user uptake and engagement with IRs. Thong, Hong and Tam (2002) apply the 'technology acceptance model' originally developed by Fred D. Davis (1989) to identify factors affecting user engagement with the related technology of digital libraries. To summarise, the technology acceptance model originally proposed by Davis posits that users' adoption of an information system is determined by two factors: *perceived ease of use* and *perceived usefulness* (Thong, Hong and Tam, 2002, p.217). *Perceived usefulness* is defined as 'the degree to which a person believes that using a particular system would enhance his or her job performance' (Davis, 1989, p.320). *Perceived ease of use*, on the other hand, is defined as 'the degree to which a person believes that using a particular system would be free from effort' (Davis, 1989, p.320).

Perceived ease of use directly impacts both 'adoption intention' because 'the easier it is for a user to interact with a system, the more likely he or she will find it useful and intend to use it' (Thong, Hong and Tam, 2002, p.217). Thong, Hong and Tam (2002) identify user interface characteristics as one of the most significant factors affecting the *perceived ease of use* of digital libraries. Extrapolating this insight to the present area of research, it is very likely that the usability of repository UIs will have a significant impact on their *perceived ease of use*, which, in turn, is likely to have a significant impact on user acceptance.

The present study will focus on usability issues from the perspective of user as information seeker, while recognising the fluidity of the distinction between 'user as information seeker' and 'user as author'. However, it is important to acknowledge that many academics will experience repository interfaces from the side of the platform that facilitates author self-archiving, as well as the front-facing

interface experienced by information seekers. Academic author engagement with repositories via self-archiving is a complex subject, in which issues of interface usability intertwine with factors including workflow processes, attitudes towards open access publishing and the wider scholarly publishing landscape. Indeed, several studies on this topic have deployed ethnographic and anthropological methods to assess the factors which impact on academic engagement with repositories via self-archiving (Allen, J., 2005; Cunningham, S.J. *et al.*, 2007; Fried Foster and Gibbons, 2005). While primarily assessing cultural factors influencing academic engagement with open access repositories, the aforementioned studies identify poor usability of the deposit UIs as a key impediment to academic self-archiving. However, less attention has been paid to usability issues in relation to 'front-facing' repository UIs as experienced by information seekers, despite the fact that many academics experience and engage with repository UIs in a way that reflects their dual role as depositing authors and information-seeking researchers (McKay, 2007b). In evaluating the usability of 'front end' repository UIs, this study will contribute to a greater understanding of usability issues impacting on information-seeking users' engagement with IRs.

As the number of repositories continues to grow, driven by the REF policy and funder mandates, it is essential that usability issues are addressed in order to ensure the ongoing buy-in of academic staff. Betz and Hall argue that 'support from faculty members is essential to ensuring that repositories can make online sharing of materials possible, along with the long-term digital preservation of these works' (2015, p.43). The usability of repository UIs has a critical role to play in ensuring the continued support of academic staff. Therefore, if IRs are to maintain their important place within an evolving scholarly communications landscape, it is essential that usability issues are addressed.

1.2 Research problem

As noted above, recent commentators (Tay, 2017; Van de Velde, 2016) have highlighted poor usability as a significant factor contributing to user non-acceptance of institutional repositories. Therefore, there is a need to identify the areas in which usability can be improved in order to better support user needs. The literature review revealed that many of the key studies in this area are over 10 years old, which suggests the need to revisit the issue of IR usability in the present day. The dissertation provided an assessment of IR usability within the context of the Scottish HEI sector, in which repository technology is relatively well established (OpenDOAR, n.d.) This assessment of usability across the Scottish HEI sector enabled a wider overview of repository usability to emerge than has hitherto been provided by existing studies, which have typically performed usability evaluations across only 1 or 2

repository interfaces. It is crucial that an appropriate evaluative framework is employed in order to successfully identify the most critical usability issues.

To tackle the problems identified above, this dissertation will address the following research questions:

- Based on a review of the literature, what criteria are appropriate to evaluate the usability of the user interface (UI) of institutional repositories?
- Judging against the identified criteria, how well do the UIs of institutional repositories of Scottish HEIs perform?
- What are the priority areas for improvement of Scottish HEI institutional repository UIs?

1.3 Research methods

The focus of the usability evaluation is on the 18 IRs provided by Scottish HEIs. Following identification of the sample, key contextual information, including type and size of institution, was collated. The heuristic evaluation method developed by Jakob Nielsen (1993) was the main component of the dissertation research. However, it was also necessary to develop a set of domain-specific heuristics in order to successfully identify usability issues presented by institutional repository UIs. This is in line with recent scholarship (Rusu *et. al*., 2010; Quiñones, Rusu and Rusu, 2018) that has highlighted the need to develop domain-specific heuristics in order to more effectively identify usability issues, which can be missed by using Nielsen's set of 10 generic heuristics.

A literature review was conducted in order to identify and consider the available definitions of 'institutional repository' and 'usability'. Thematic coding of the literature review was conducted in order to identify the key features of IR usability identified by previous studies. The identified features were then mapped against Nielsen's 10 heuristics, in order to identify any gaps or areas of overlap. Following the mapping exercise, a set of 14 novel domain-specific heuristics was proposed. This new set of domain-specific heuristics was then used as the basis for the subsequent evaluation of the 18 Scottish HEI IR user interfaces. The resulting data was analysed in order to determine the priority areas for improvement of IR interface usability.

1.4 Research outcomes

Considering that IRs have been implemented in the majority of Scottish HEIs for over 10 years and that, more generally, the technology has reached a certain stage of maturity (Nicholas *et al*., 2013), it is hoped that this study will contribute towards a better overview and understanding of the current repository landscape within Scotland, focusing particularly on the issue of usability.

One of the outcomes of this research has been to develop a novel set of domain-specific heuristics, designed specifically to evaluate the usability of institutional repositories. It is hoped that this new set of heuristics will be a useful tool for repository and usability evaluation professionals. The new domain-specific heuristics will be employed in the evaluation of the 18 Scottish HEI repository interfaces.

A better, in-depth exploration of the usability issues present within Scottish HEI repository interfaces will be useful for repository managers and systems developers who are looking to improve the usability of the platforms that they provide which, in turn, will help to promote increased user engagement. Identification of the most serious usability issues will allow for the prioritisation of time and resources to address those areas.

Given that many of the usability studies on institutional repositories identified in the literature review were published in the earlier period of the technology's development, it is hoped that the present study will prompt renewed attention to this issue, as an important factor in relation to user engagement.

1.5 Learning outcomes

The desired learning outcomes for the researcher are: to develop an understanding of the concept of usability in the field of human-computer interaction; to develop knowledge and experience in the area of heuristic evaluation; to gain experience in performing quantitative data analysis; to develop knowledge of the factors affecting IR usability; and to gain an in-depth understanding of usability issues relating to Scottish HEI repositories.

1.6 Overview of structure

The main body of this dissertation is structured by the following 7 sections:

- **Section 1 – Introduction.** The introductory section sets out the research context, research questions and the research methods. The section then outlines the intended research and learning outcomes.
- **Section 2 – Literature Review.** Section 2 presents the results of the literature review. Analysis of the literature review identified key themes which were then mapped against Nielsen's (1993) set of 10 usability heuristics. The outcome of this mapping provided the basis for the development of a new set of 14 domain-specific heuristics.

- **Section 3 – Methods.** Section 3 describes the research methods employed to carry out the research, outlining and providing justification of the main components. Limitations of the research methods are also discussed.
- **Section 4 – Results.** Section 4 presents the results of the usability evaluation of the 18 Scottish HEI repository interfaces. The section begins with a presentation of the overall results, then provides a breakdown of results by software type, institution type and heuristics. Priority areas for improvement are identified.
- **Section 5 – Discussion of Results.** Section 5 provides a discussion of the results, following the same structure as Section 4. Results are discussed in relation to the literature review, with key points of comparison and contrast identified.
- **Section 6 – Recommendations.** Section 6 provides recommendations derived from the analysis of the results, designed to improve the usability of Scottish HEI repository interfaces. Furthermore, this section provides recommendations designed to address the limitations of the present study, including recommendations for future research.
- **Section 7 – Conclusions.** Section 7 provides concluding reflections on the research questions and methods, before moving on to a reflection on the research and learning outcomes. This section culminates in concluding comments in relation to the dissertation overall.

Section 2.0 - Literature Review

2.1 Definitions of institutional repository

There are multiple definitions of the term 'institutional repository'. Definitions tend to reflect either a systems or services-based approach, depending on each author's perspective. For example, Raym Crow offer a systems-based definition of an institutional repository as:

> A digital archive of the intellectual product created by the faculty, research staff, and students of an institution and accessible to end users both within and outside of the institution, with few if any barriers to access (2002, p.3).

Similarly, Sally Rumsey offers a definition of an institutional repository as an 'open access […] searchable, digital archive of materials emanating from an institution' (2006, p.181). In contrast, Lynch adopts a services-based approach in outlining his definition of an institutional repository as:

> a set of services that a university offers to the members of its community for the management and dissemination of digital materials created by the institution and its community members (2003, p.328).

Furthermore, Lynch states that 'It [IL] is most essentially an organizational commitment to the stewardship of these digital materials' and includes 'long-term preservation' as well as 'organization and access or distribution' among its core functions (2003, p.328).

Similar to Lynch, Mike Furlough argues against any definition that would reduce repositories to only their technological apparatus. Furlough states that, 'when we are talking about repositories, we are talking about a set of organized methods for content management, not about specific applications or even specific access points online' (2009, p.19). In the UK, Jisc proposed a working definition of 'repository' which has been endorsed by RLUK, SCONUL, ARMA and UKCoRR. The Jisc definition is explicitly derived from Lynch's definition but has been modified slightly to reflect the fact that repositories may be provided by research organisations other than universities. The Jisc definition reads:

> A repository is a set of services that a research organisation offers to the members of its community for the management and dissemination of digital materials created by its community members (Jisc, 2016).

This thesis will adopt the Jisc definition, while recognising that 'repository' has meant and continues to mean different things in different contexts.

2.2 Definitions of usability

As Judy Jeng notes in relation to the scholarly literature on digital libraries, the 'most widely cited definitions of usability are those provided by ISO Standard 9241-11 and by Nielsen's 1993 study *Usability Engineering'* (2005, p.97). The ISO standard defines usability as, 'the extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use' (2018). Notably, the ISO definition does not prescribe a specific set of operational criteria against which the attributes of effectiveness, efficiency and satisfaction should be measured. Nielsen defines usability in terms of five attributes: 'learnability, efficiency, memorability, low error rate, and satisfaction' (1993, p.26). Nielsen defines 'satisfaction' in subjective terms, stating that 'the system should be pleasant to use, so that users are subjectively satisfied when using it; they like it' (1993, p.26).

Other studies describe usability in similar terms. Brian Shackel defines usability according to the four attributes of 'effectiveness, learnability, flexibility, and attitude' (1991, p.23). For a system to achieve success in relation to attitude, Shackel states that it must operate 'within acceptable levels of human cost in terms of tiredness, discomfort, frustration and personal effort' (1991, p.23). Furthermore, for a system to be flexible, Shackel states that it must allow 'adaptation to some specified percentage variation in tasks and/or environments' (1991, p.23) beyond those initially specified. Paul Booth (1989) acknowledges his debt to Shackel's earlier work to define usability. However, he argues against the inclusion of 'flexibility' as an attribute of usability, because it is too difficult to specify and measure in an operational environment. Instead, Booth proposes that the attribute of 'flexibility' be replaced with that of 'usefulness', defined in terms of how well a system helps users to achieve their goals (1989, p.112). Therefore, in Booth's definition, usability is defined in terms of the four attributes of 'usefulness, effectiveness, learnability and attitude' (1989, p.112).

Similarities persist in later definitions of usability. Tom Brinck (2002), for example, defines usability as the extent to which the system manifests the design goals of being functionally correct, efficient to use, easy to learn and remember, error tolerant and subjectively pleasing. Oulanov and Pajarillo (2002) define usability in terms of the five attributes of affect, efficiency, control, helpfulness and adaptability. They emphasise the significance of their inclusion of 'adaptability' as a category that reflects the way in which users not only learn to use a particular product, but also adapt to the 'physical, physiological and psychological' aspects that usage entails (2002, p.484). While encompassing the idea of learnability as found in earlier definitions of usability, Oulanov and Pajarillo's attribute of 'adaptability' expands beyond this, to incorporate wider environmental factors. Lee (2004) describes usability in terms of four categories of usefulness, effectiveness, satisfaction, supportiveness and intuitiveness. This increased definitional expansiveness is also manifested in the usability

guidelines produced by MIT (2004) which specify ten attributes including design/layout, navigation, terminology, error prevention, functionality and visual clarity.

Two separate studies by Jeng (2005) and Kim and Kim (2008) cite Pearrow's definition of usability as being most representative of all the definitions surveyed. Pearrow defines usability as 'the greatest ease of use, ease of learnability, amount of usefulness, and least amount of discomfort' for users (2000, quoted in Jeng, 2005, p.99). Jeng (2005) uses Pearrow's definition as the basis of an evaluative model which she adapts to test the usability of the Rutger's and Queen's University library websites. Jeng (2005) drew on the attributes of effectiveness, efficiency, satisfaction and learnability, as well as further identified sub-attributes, as the basis for user testing. The results suggested the interlocking nature of the relationships between these attributes, with Jeng (2005) identifying a reciprocal relationship between effectiveness and satisfaction. Similarly, Soohyung Joo (2010) investigated the nature of the relationship between satisfaction, effectiveness, and efficiency, and found an extremely high correlation between satisfaction and effectiveness and between satisfaction and efficiency. Considering these findings, Joo (2010) suggests the redundancy of satisfaction as an attribute that is strongly dependant on the other usability attributes of effectiveness and efficiency. Based on this review of the literature, the attributes of effectiveness, efficiency and learnability emerge as the key attributes of usability.

2.3 Users of institutional repositories

Who are the users of institutional repositories? Dana McKay (2007a) identifies three main user groups of 'authors, information seekers, and data creators/maintainers'. While McKay (2007a) identifies that authors have received a relatively high level of attention, she states that less is known about data maintainers/creators or information seekers. McKay (2007a) argues that this lack of attention to these two key user groups has hampered the development of IRs, as usability issues are not being sufficiently identified or addressed. She argues that this results in frustration among the very group of professionals charged with implementing and maintaining IRs. The early distinction made by McKay (2007a) between authors, data maintainers/creators and information seekers has influenced subsequent studies. For instance, Rachel Walton draws on McKay's characterisation to describe the dual-nature of IR 'user-friendliness' (2018, p.25) in terms of users of the front-facing public interface and users of the back-end administrative interface. Published eleven years after McKay's article, Walton still maintains that comparatively little is known about IR 'information seekers' and 'data maintainers' compared to what is known about authors. Resonating with McKay, Walton (2018) argues that this comparative lack of attention occludes our ability to evaluate IRs in terms of their usability for these user groups. Beth St. Jean *et al.* similarly argue that end users are 'seldom heard

from' (2011, p.21). The authors note that much of the existing IR literature used the term 'user' to refer to authors, rather than information seekers and has focussed attention on issues of content recruitment, more than on usability. In this respect, the authors argue that the lack of attention to end users in the scholarly literature contributes to a 'chicken-and-egg' problem (St. Jean *et al.*, 2011, p.23) in which authors do not see the value of contributing to a platform which they themselves are not expected to use. Yet, as she argues, it is crucial to recognise the dual nature of IR end users as both authors and information seekers, as these groups are often constituted by the same set of people.

St. Jean *et al.* (2011) acknowledge the earlier work of Pickton and McKnight in identifying 'research students' as a key *potential* end user group. Pickton and McKnight (2007) conducted a short email survey in order to investigate the views of repository managers regarding IR use by research students, as either/both authors and readers. Reflecting the wider scholarly literature, the results showed that 'IR students have significantly more information about research students as authors than about research students as readers' (Pickton and McKnight, 2007, p.156). Despite this lack of knowledge, the survey results indicated that repository managers overwhelmingly recognised the potential of research students to contribute to IRs as authors or readers (or both) (Pickton and McKnight, 2007).

The findings of a later study by Waugh *et al.* (2015) support Pickton and McKnight's earlier suggestion of the untapped potential of research students as users of IRs. This study by Waugh *et. al.* investigated the value of the University of North Texas' (UNT's) digital repositories as perceived by UNT faculty, staff, and graduate students. The authors created a Qualtrics survey, which included quantifiable questions for data collection. The survey was administered to faculty, staff and graduate students at UNT in 2013 and received a total of 785 responses, or 6.7% (Waugh *et. al.*, 2015, p.746). The survey results indicated that graduate students placed greater value in the repository compared to faculty, even accounting for disciplinary differences. Graduate students were also 'twice as likely as either faculty or staff to contribute academic outputs' (Waugh *et. al.*, 2015, p.748) to the repository. Moreover, the results indicated a direct relationship between value placed in the IR and willingness to contribute, with willingness to contribute increasing in line with perceived value (Waugh *et. al.*, 2015). Similarly, use of the resources increased directly in line with the perception of increased value of the resources (Waugh *et. al.*, 2015). Notably, graduate students were significantly more enthusiastic than faculty or staff in their willingness to use and contribute to the IR (Waugh *et. al.*, 2015). As these studies by Pickton and McKnight and Waugh *et al.* suggest, research students are a potentially substantial IR user group that exemplify the dual nature of users as authors and contributors. Despite these important contributions in identifying *potential* IR users, St. Jean *et al.*'s 2011 article remains

significant as the most comprehensive attempt to understand the perceptions and experiences of IRs by information-seeking end users to date.

2.4 Usability evaluation

2.4.1 Evaluating institutional repositories: personas

Within the literature review, two articles were found that use personas to represent potential end users of IRs, in order to identify usability issues (Aljohani and Blustein, 2015; Maness, Miaskiewicz and Sumner, 2008). Aljohani and Blustein (2015) drew on Alan Cooper's (1999) original idea of using user profiles or 'personas' to create fictitious people representing the personalities and goals of potential user groups. As Lene Nielsen explains, 'The persona method does not include real users in the design process, but instead has representations of users' (2019, p.4). Moreover, Nielsen (2019) identifies that personas are essentially qualitative in nature, attempting to present a holistic understanding users as human beings, to better understand their needs and wants in relation to a specific system or product.

In their study, Aljohani and Blustein (2015) evaluate the institutional repository at Dalhousie University, Canada (DalSpace). The study used focus groups and interviews to 'create personas that represent potential end users of a university repository service' (Aljohani and Blustein, 2015, p.629). To create the personas, the authors conducted a focus group of six (undergraduate and postgraduate) students. The participants suggested user groups who might use DalSpace. Following identification of potential groups, the participants assigned attributes to each group. Attributes were organised under each user group to establish four user profiles. The final results included four personas and 18 task scenarios which were then used to perform a heuristic evaluation of DalSpace. The four personas were: a 20- year old undergraduate student named Rebecca, a 25-year old master's student named Thomas, a 26- year old PhD student named Ishan and a construction and reference librarian persona (with no age or name).

Focus group participants identified differences in relation to which aspects of IR functionality would be most useful for each persona. With respect to the undergraduate persona, some participants suggested that it would be useful for users to be able to comment on content. Focus group participants identified that it would be helpful for master's students to receive email notifications when new content is uploaded in an area of interest. All focus group participants agreed that PhD students would find it useful to access information on their supervisor, including all publications, as well as theses which they have supervised. With respect to the construction and reference librarian persona, it was felt that they would benefit from a search interface that would aid recall and precision. Moreover, it was felt that the reference librarian would find it highly useful to view accurate statistics and analysis in relation to usage of repository content. The 18 task scenarios employed were based on the four

personas and were designed to reflect the 'most important elements derived from the personas' (Aljohani and Blustein, 2015, p.634). A heuristic evaluation of the DalSpace repository was completed based on the proposed task scenarios. Recommendations for improvements to the DalSpace interface were then suggested based on the results of the heuristic evaluation.

Maness, Miaskiewicz and Sumner (2008), used personas to inform the design of the IR at the University of Colorado at Boulder (UCB). Interviews were conducted with 'eight graduate students and twelve members of faculty' (2008), recruited across several disciplines. Semantic analysis of the interview transcripts yielded four different personas as follows: a 61-year old male professor of history named Charles Williams, a 28-year old male doctoral student in biology named Rahul Singh, a 44-year old female professor of education named Anne Chao and a 21-year old female doctoral student in psychology named Julia Fisher. Development of the personas revealed issues that have implications for the IR design. While all personas expressed a willingness to contribute material to the repository, it was felt that Professor Charles Williams would benefit from an intermediary liaison member of staff to assist him with the deposit process. Common to all four personas was the desire to use the IR to access grey literature, including learning and teaching materials. Professor Anne Chao wanted to be able to extract content from the IR to automatically populate her own personal website. Rahul Singh wished to use the IR primarily as an academic networking platform and would like to be able to establish his presence via development of a user profile. Finally, Julia Fisher would like to use the IR to share work-in-progress, such as pre-publications, and be able to engage others via the platform to provide ongoing feedback.

2.4.2 Evaluating institutional repositories: user testing

Several studies have employed user testing as a method of evaluating IRs. The work in this area has been informed by earlier studies, notably Jeng (2005), which employed user testing to evaluate the usability of digital libraries. As mentioned earlier, Jeng's development and assessment of an evaluative criteria to test the usability of digital libraries indicated a strong correlation between the attributes of effectiveness and satisfaction. Whereas Jeng's study sought to bring a late assessment of usability to a mature library technology, Jihyun Kim (2005) provided an early assessment of the usability of IRs at a relatively early stage of their development. This study by Kim (2005) used a combination of heuristic evaluation and user testing involving eighteen undergraduate students to compare the usability of the interfaces of Dspace and Eprints. Both systems had been implemented concurrently at the Australian National University (ANU), based on the same set of digital documents. The study involved the users completing a set of ten tasks on both DSpace and EPrints. The tasks were designed specifically to assess the usability of the search and browse features. Post-testing questionnaires were also used to

assess users' satisfaction with the overall design of each interface. The results showed that, overall, both simple and advanced searching was performed faster and with fewer errors in DSpace than in EPrints. However, users found it faster and easier to complete the browsing task in EPrints rather than DSpace. As a whole, DSpace users spent less time completing tasks than EPrints users and made fewer errors. Kim draws on the results of the usability testing to propose seven operational criteria for evaluating the design of user interfaces in IRs. The criteria proposed by Kim (2005) are explicitly shaped by Jakob Nielsen's influential set of 10 usability heuristics, which are as follows: simple and natural dialogue, speak the users' language, minimize the user's memory load, consistency, feedback, clearly marked exits, shortcuts, good error messages, prevent errors, and provide help and documentation' (1993, p.20). Adapted from Nielsen's usability heuristics, the operational evaluative criteria for IRs proposed by Kim (2005) are: provide users with an adequate number of search options, provide examples of search queries, employ user's language, allow users greater control and freedom, display useful components in result sets, list search results in a useful way, clearly present links to be able to open digital documents.

Rea Devakos (2006) provided a study of the usability of the University of Toronto's IR, known as -T-Space. The study was conducted at an early stage of the implementation of the IR within the institution. Qualitative research methods were used to garner initial feedback from early adopters and then, at a later stage, from library staff. During the initial 18 months, open-ended interviews were conducted with early adopters. The initial results from the early adopters raised key concerns of visibility of deposited material, versioning, lack of enthusiasm among academic colleagues, as well as issues with inconsistencies and incompleteness of metadata. Moreover, early adopters expressed concern that the community model supported by DSpace (the software used to support T-Space) had been implemented in a way that reflected bureaucratic institutional units, but not the 'real' disciplinary communities fostered by academics from the ground up. Later interviews conducted with library staff yielded concerns regarding the incorporation of new tasks into existing heavy workloads, and lack of knowledge and expertise in developing and implementing this new technology. In conclusion, Devakos argues that the successful implementation of an IR involves balancing multiple, competing priorities.

Davis and Connolly (2007) approached usability issues from a different angle, exploring the reasons for *non-use* of IRs. Davis and Connolly collected data from Cornell University's DSpace interface, along with 'web server log files detailing visits to DSpace' (2007, p.5). The same type of automated data collection was performed on seven other institutions that used DSpace, to provide the basis for comparative analysis. Supplementary information in relation to the attitudes, motivations and behaviours behind non-use was obtained via eleven semi-structured interviews with faculty

members. The results of the study indicated several reasons for *use* of IRs, including permanence/preservation, funder mandating, timeliness of dissemination, and the formal registration of ideas. However, these incentives were balanced against several reasons for IR *non-use*, including the learning curve involved in learning a new technology, concerns with copyright, ambiguity surrounding what constitutes 'publication' and how this might affect publication in other avenues, concerns over quality of content, fears of plagiarism, and concerns over reputation. Moreover, Davis and Connolly identified reasons for non-use specific to DSpace, including 'a perceived lack of software functionality' (2007, p.15). As was also reported by Devakos (2006), the 'categories' used by DSpace were felt to be inflexible and did not allow users to 'delete, move objects, or cross-list objects against categories' (Davis and Connolly, 2007, p.15). Furthermore, participants in the Davis and Connolly (2007) study indicated that lack of awareness of the existence of their institutional IR was a major reason for non-use among their colleagues. Compared with other institutions using DSpace, the lack of content in Cornell's IR also emerged as a contributing factor to non-use.

As mentioned briefly above, Kim and Kim (2008) were influenced by Pearrow's (2000) definition of usability in terms of the attributes of effectiveness, efficiency, satisfaction and learnability. The authors adopted this definition to facilitate structured focus group testing of the consortium of South Korean IRs known collectively as 'dCollection' (Kim and Kim, 2008, p.863). The focus group testing revealed usability issues of navigability, page layout and interface design. Kim and Kim used the results of their study to suggest improvement to the dCollection IRs. The suggested improvements included applying a FRBR model to the search and browse functions, and improving the page layout, design and navigation structure.

St. Jean *et al.* (2011) attempted to redress the gap in our knowledge of IR end users by conducting interviews with 20 participants recruited across ten different institutions. Results of the interviews revealed that users varied in their awareness of the nature of IRs and demonstrated uncertainty regarding the scope of the content that they contain. Moreover, interview subjects were uncertain about the meaning of the term 'institutional repository', with several interviewees conceptualising it in metaphorical terms as a kind of large drawer. Moreover, many of the interviewees were unclear as to the distinction between IRs and library databases such as JSTOR. St. Jean *et al.* state, 'it was apparent that many of them were uncertain about what exactly constitutes an IR' (2011, p.29). Results indicated that most of the interviewees reached the IR via their university library's homepage (St. Jean *et al.,* 2011, p.29). Participants in this study reported using a wide variety of search strategies, and limiting searches to particular collections within the IR. Moreover, users reported employing various browsing strategies, including 'browsing by author, title, subject, and

date, as well as browsing through communities and collections, researcher pages' (St. Jean *et al.,* 2011, p.30).

The study identified a range of key benefits which IR end users associated with using IRs. These included: availability/convenience of the resource, ability to access content soon after it has been produced, to access content that is not available via other channels, ability to use just one centralised resource to locate a diverse range of material, and 'the ability to identify potential networking and collaborative opportunities' (St. Jean *et al.*, 2011, p.37). Despite the perceived benefits of IRs, a key finding of the study by St. Jean *et al.,* is that users demonstrate diverse understandings of what they are and what they contain. While the results indicated that users value the variety of content that they are able to locate within IRs, they were also uncertain about the scope of the content and whether or not it had been peer-reviewed. Taking this into consideration, St. Jean *et al.* argue that users would benefit from 'clear definitions and delineations of scope on IR homepages' (2011, p.39). Furthermore, the authors report that several factors influence the likelihood of users returning to the IR, including 'the visibility of the IR, the unique nature and limitations of the content available through the IR, the perceived quality of IR content, the look and functionality of the IR, and any interactions between the extent of content in the IR and its functionality' (St. Jean *et al.*, 2011, p.40). Based on these findings, St. Jean *et al.* conclude that increased visibility of the IR, wider range of content and improved appearance and functionality of the user interface would benefit future IR development.

Luca and Narayan (2016) describe the process whereby the institutional repository of the University of Technology, Sydney (UTS) was evaluated and then redesigned following a usability evaluation. The authors developed a set of seven usability criteria based on Nielsen's heuristic evaluation method to assess the UTS repository. The study involved six participants (two IS researchers, two IS students and two librarians) who performed usability analysis of the repository conducted via 'paired co-discovery and analysis with dyadic participant pairs' (Luca and Narayan, 2016, p.278). A key finding of the usability assessment was that the visual design of the repository could be redesigned to better reflect disciplinary communities. Furthermore, users found library-derived terminology/jargon confusing. In contrast, users found it helpful when terminology/jargon were explained via graphic visualization. Following the usability analysis, the authors redesigned the UTS repository to create a more user-friendly visual design and graphic visualization of key processes.

While it does not employ user testing, Walton's (2018) recent article draws on her own experience as an IR manager, to propose a set of ten usability criteria for IR end users and managers. Walton draws on the distinction made by McKay (2007a) between three groups of IR end users: information seekers, authors/submitters and 'data maintainers'. In so doing, Walton describes the 'front' and 'back' ends as two separate, but equally important, aspects of a repository platform, which

engage distinct user groups. Walton (2018) endorses the set of seven usability criteria proposed by Kim (2005) as still relevant and applicable to IR evaluation. Walton argues that the evaluation criteria established by Kim remain highly useful but suggests three additional criteria that could bring the framework up-to-date. These three additional criteria are 'The contents of the site are highly visible and discoverable on the open web', 'the interface offers a pleasing aesthetic and minimalist design' and 'appropriate web 2.0 features enhance functionality' (Walton, 2018, p.26). The evidence to support the inclusion of these three additional criteria are based largely on the author's own experiences as an IR manager and also St. Jean *et al.*'s 2011 study of IR end users. Walton concludes the article by saying she hopes that the new list of ten criteria which she proposes will prove useful to IR managers and librarians in evaluating the usability of their platforms.

Section 3.0 Methods

3.1 Brief overview of components of the research design

Heuristic evaluation was the main component of the dissertation research, but it was necessary to first of all develop a set of domain-specific heuristics suitable to evaluate the IR user interfaces. This was intended to address recent concerns that performing evaluations based solely on general sets of heuristics, such as Nielsen's widely used 10 usability heuristics, can fail to identify usability problems specific to certain domains (Rusu *et al.*, 2010; Hermawati and Lawson 2016; Van Greunen and Pottas, 2011). While no consensus exists as to the best method to create domain-specific usability heuristics, the overarching principle of developing heuristics based on a literature review is widely accepted (Hermawati and Lawson, 2016). In line with the methodology recently proposed by Quiñones, Rusu and Rusu (2018), qualitative analysis of the literature review was completed to identify features that could serve as the basis for a set of corresponding heuristics. The resulting heuristics were then matched against Nielsen's heuristics to identify areas of overlap and then a new set of heuristics was proposed. This new set of heuristics was used as the basis for the subsequent heuristic evaluation of the IR user interfaces. Analysis of the resulting data was used to determine the priority areas for improvement of IR usability. Each component of the research design will be discussed in greater detail, below.

3.2 Identifying the sample and gathering information

The focus of the usability evaluation is on the IRs of Scottish higher education institutions (HEIs). Institutional repositories have been established within several Scottish HEIs since the early period of this technology's development. Overall, the Scottish repository landscape has reached a relatively mature stage of development. In light of this, an analysis of IR usability within the Scottish HEI sector will provide insight into this issue within a context in which the technology is relatively well-established. Scotland's higher education sector possesses institutions of a range of types and historical origins. In this respect, the research can provide an insight into how repository usability varies across different types of institutions, from ancient to post-1992 universities. According to a report produced by The Scottish Parliament, there are a total of 19 HEIs in Scotland (2016, p.3). The report classifies Scottish HEIs into 6 different types: ancient universities, chartered universities, post-1992, partnerships of colleges, the Open University and specialist institutions (The Scottish Parliament, 106, p.2). Three of the HEIs in Scotland are not universities: Glasgow School of Art, The Royal Conservatoire of Scotland and Scotland's Rural College (SRUC). Each of the 19 Scottish HEIs has its own institutional

repository, with the exception of The Royal Conservatoire of Scotland (RCS). The University of St Andrews provides repository services for the RCS. **Appendix 1** provides the full information gathered in relation to Scottish HEIs, including institution size, type and software used to provide repository services.

3.3 Consideration of usability inspection methods

There are multiple methods available to evaluate the usability of a user interface. The most common of these methods are user testing and expert evaluation (heuristic evaluation or cognitive walkthroughs) (Pickard, 2007, p.227). Consideration was made of the different usability methods and their applicability to meeting the goals of the research. As Nielsen acknowledges, deciding on which usability inspection method must be informed by 'broader considerations, including the relative effectiveness of results provided by the method and how easy methods are to learn and use' (1994a, p.8). The latter factor was of particular consideration, given the researcher's relative lack of experience in this area. User testing was considered because it is a common method of approaching user-centred design and because it could provide data on how users actually interact with the different repository interfaces. However, there are several reasons why this usability inspection was disregarded. Given the scope of the research, it would be overly taxing and time consuming to ask a group of test users to test across multiple repository interfaces. Moreover, the researcher has no background or experience of performing user testing and this is likely to have impacted negatively on the process.

Having decided against employing user testing, the different methods of 'expert evaluation' were considered. Cognitive walkthroughs involve 'simulating a user's problem-solving process at each step in the human-computer dialogue, checking to see if the user's goals and memory for actions can be assumed to lead to the correct action' (Nielsen, 1994a, p.6). Cognitive walkthroughs are typically used by system developers during the design process (Pickard, 2007). This method uses a task-based approach to identify typical patterns of user behaviour and record any problems encountered in using the system. Cognitive walkthroughs require a high level of systems knowledge on the part of the evaluator, as he/she must have a sufficient level of understanding to be able to interpret what is happening during the process and how the systems design influences problems and their potential solutions. As Nielsen acknowledges, 'one of the main criticisms of cognitive walkthroughs is that the approach is not easy to learn or to apply' (1994a, p.12). As in the case of user testing, limitations of time, resources and expertise of the researcher militated against the selection of cognitive walkthroughs as the usability inspection method. Moreover, cognitive walkthroughs are most often performed during the design process in order to identify problems to inform amendments to system

design as it is being developed (Pickard, 2007). As such, this method is not directly applicable to the goals of the present research.

3.3.1 Heuristic evaluation

Heuristic evaluation is a specific method of expert evaluation, which was originally developed by Nielsen (Nielsen, 1994a; Brinck, 2001; Pickard, 2007). Nielsen states, 'Heuristic evaluation is done as a systematic inspection of a user interface design for usability' (1994a, p.25). Heuristic evaluation is a widely used method to identify problems with the usability of a system. Heuristic evaluation involves an evaluator(s) examining an interface using a set of identified guidelines ('heuristics') and assessing the level of compliance (Pickard, 2007). Unlike cognitive walkthroughs, heuristic evaluations are not task-based and allow the evaluator to adopt a more free-flow, open-ended approach to evaluation (Pickard, 2007; Nielsen, 1994a). As Nielsen argues, one advantage of this more open-ended approach is that it better reflects the behaviour of real users, who will 'generate their own goals and combine exploration, inference and training to map them into interface actions' (1994a, p.9).

Nielsen recommends that evaluators review the interface 'at least twice' (1994a, p.29). On the first 'pass', the evaluator moves through the system to familiarise him/herself with the general scope and navigation structure, to get an overall feel for the system. On the second pass, the evaluator then focusses on the specific elements of the interface related to the heuristics (Nielsen, 1994a; Pickard, 2007). Heuristic evaluation is commonly referred to as a 'discount' usability inspection method, because it is relatively fast and easy to conduct (Nielsen, 1994a, p.25). In this respect, this method was ideally suited to the present research, in which time and resources were limited. Furthermore, the degree of compliance of an interface to heuristics can be measured by recording severity ratings for any violations that occur (Nielsen, 1994a). The use of severity ratings will be described in greater detail, below. Recording the severity ratings of violations that occur enables subsequent usability improvements to be prioritised. In this way, the method directly supports one of the research goals, to identify priority areas for improvement of IR usability.

3.3.2 Limitations of heuristic evaluation

There are several widely recognised limitations to heuristic evaluation as a usability inspection method. Although a single evaluator can perform a heuristic evaluation of a user interface, there is a better possibility of uncovering the full range of usability issues if several evaluators are used (Nielsen, 1994a). To address this, Nielsen suggests using between 3 and 5 evaluators. If more than 5 evaluators are used, the overlap of the issues identified outweighs the benefits of using the additional evaluators (Pickard, 2007). However, only one evaluator was available for the present study. Taking this into

consideration, the 'two-pass' process recommended by Nielsen and Pickard, as discussed above, was used by the researcher, to ensure that a thorough evaluation of each interface was conducted.

Another limitation of the use of heuristic evaluation for the present study is the limited experience of the evaluator. A study by Nielsen (1992) showed that the level of expertise of the evaluator had a direct bearing on the number of usability problems found, with evaluators possessing a greater level of expertise uncovering a higher proportion of the usability problems. de Lima Salgado and de Mattos Fortes (2016) developed a classification scheme to rate the level of expertise of evaluators and found that 'novice' evaluators (those without a relevant university degree and very limited practice in usability evaluation) struggle in particular to uncover usability issues pertaining to heuristics three and seven of Nielsen's schema, 'user control and freedom' and 'flexibility and efficiency of use'. Taking this into consideration, it is important to acknowledge the limited expertise of the researcher as one limitation of the present study. However, it is hoped that the methods proposed may be validated in future research by those with more expertise in this area. Furthermore, heuristic evaluation cannot capture the variety of real users' behaviour (Preece, 1993; Brinck, 2001). For this reason, heuristic evaluation is often performed prior to user testing (Nielsen, 1994a; Macgregor, 2011). While this is not possible within the scope of the current study, it is hoped that the methods proposed may provide a useful framework for future research that may employ user testing of IR interfaces.

3.4 Literature review

Conducting a literature review is a complex process which involves the interpretation of varied sources on a given topic and involves summarisation, analysis and synthesis of results (Ongwuegbezie *et al.*, 2016). The present study draws on the recommendation of Onwuegbuzie *et al.* (2016) that a transparent, systematic and meaningful approach be followed in order to mitigate against common pitfalls such as confirmation bias, or the tendency to extract only information that endorses the researcher's opinion (Ongwuegbezie *et al.*, 2016). A search log was maintained during the literature review process, with records kept of search strings, databases or search engines used and information about relevant results obtained. The main databases used during the search process were Library & Information Science Abstracts (LISA) and Library, Information Science & Technology Abstracts (LISTA). Google Scholar was the main search engine used, while SuPrimo was also used to interrogate content accessible via the university library.

A search log and record of relevant results was recorded and stored in Excel. Information about the relevant results obtained was arranged under column headings including the following: full citation, year of publication, type of source, topic(s) and summary. Recording year of publication under

a separate column heading enabled the data to be sorted longitudinally, from earliest to most recent date. Key words identified by the researcher were recorded under the 'Topic' column heading, to facilitate synthesis and cross-comparison of the sources. Similarly, a short summary paragraph of each source was created to serve as an *aide memoir* for the researcher. Sorting the data in chronological order revealed a pattern of results, with clusters emerging within two time periods; one in the earlier stages of the adoption and implementation of IRs worldwide (2005-2008), and the second at a later stage when IRs had developed a level of maturity in their development and use (2011-2016). Fewer scholarly articles were retrieved in the period between the two clusters mentioned and also in the period 2016 to the present day, the latter observation supporting the motivation of this research to consider the issue of IR usability in the present day. While results included sources retrieved from around the globe, a focus was maintained on recording those results from developed, rather than developing countries, due to the higher level of relevance to the current research context. Within the results obtained from developed countries, a higher proportion of articles were available from the USA, Canada or Australia with respect to the United Kingdom.

Overall, the literature review process revealed a lack of scholarly attention to the specific issue of IR usability or user needs within a UK, let alone Scottish, context. Work by Rumsey (2006), Pickton and McKnight (2007), Zuccala, Watson (2007) Oppenheim and Dhiensa (2008) and Russell and Day (2010) are notable for their focus the relationship between users and IRs within the UK context. Within a Scotland-specific context, a recent article by Macgregor (2018) provides an evaluation of techniques employed to boost the discoverability and web impact of Strathprints, the repository of the University of Strathclyde. By following links accessed via the Open Access Scotland Group blog, the researcher also identified recent presentations by Alistair (2018) and Ramage and Gibson (2017) that described the service provision and support offered to academics at the universities of Edinburgh and Edinburgh Napier, respectively, in relation to their institutional repositories. However, the literature review process did not uncover any material with a focus on IR usability, user needs, or usability evaluation within a Scotland-specific context.

A selection of the retrieved articles was made, to serve as the basis for subsequent coding, with a view to draw on the derived codes to develop a new set of domain-specific heuristics. The selection of which articles to include in the set for coding was made on the basis of the following: relevance to the research questions, authority of the publication (based on the author's credentials, institutional affiliation, place of publication, whether it was peer-reviewed), relevance to the research context (favouring articles which focused on developed countries, albeit noting the lack of scholarly material on this specific topic originating within the UK), relevance of the research methods used (for example, studies which used appropriate methods such as heuristic evaluation, user testing or

personas). Only studies developed from primary research were included in the set of articles selected for coding. For this reason, relevant articles by McKay (2007a), Russell and Day (2010) and Walton (2018) were excluded from the selection as they offered commentary on pre-existing user studies. Based on these criteria, a total of eleven articles were selected for coding. See **Appendix 2** for a full list of the articles that were selected for coding.

3.4.1 Coding of the literature review

Coding of the articles was performed in nVivo (version 12). Coding of the articles was conducted in order to extract information and was chosen as an effective and efficient means to identify key themes that could be used in the process of developing domain-specific heuristics, as will be outlined in further detail, below (Van Greunen and Pottas, 2011). Ongwuegbezie *et al.* (2016) recommend utilising one or more of Johnny Saldaña's well-known coding methods and adopting a systematic approach when extracting information from the literature review, as a means to ensure fairness and authenticity. Each of the selected articles was uploaded to nVivo to enable a structured coding process. The researcher began analysis with initial (or 'open') coding of each article in sequential order, developing tentative codes by extracting textual data at the sentence or paragraph level in to nVivo 'nodes'. In analysing the textual data, the researcher drew on the grounded theory approach as developed by Strauss and Corbin (1998). Strauss and Corbin assert that a value of grounded theory is its ability to ground theory in data. They explain, 'the concepts out of which the theory is constructed are derived from data collected during the research process and not chosen *prior to* the research.' (Strauss and Corbin, 2015, p.7) The researcher drew on this approach in order to allow key themes to emerge from the selected usability studies, rather than attempting to fit the data to any pre-conceived framework. This methodology was employed in an attempt to let the users' voice find expression in the codes and, ultimately, the heuristics that would emerge. The initial coding was conducted iteratively, drawing on the process of 'constant comparisons' described by Straus and Corbin (2015, p.7). That is, provisional codes were created as each article was read in turn, and data that was similar in nature was coded under the same provisional heading.

After the initial coding of each article had been completed, the provisional codes that had emerged were considered further. This involved reviewing the textual content that had been extracted to each node, noting the number of references and level of article coverage within each node, as well as the number of files that data had been extracted from. Following completion of the initial coding, axial coding was conducted to consolidate the codes. Ongwuegbezie *et al.* describe axial coding as a method appropriate to the 'second cycle' of analysis, in which processes including 'classifying, prioritizing, integrating, synthesizing' (2016, pp.133-134) are completed. The authors further define axial coding as 'grouping/sorting/reducing the number of codes generated from the

first cycle of coding' (Ongwuegbezie *et al.*, 2016, p.134) by synthesization, as well as removal of redundant codes. For example, a provisional code of 'browsing by different content type' was synthesised with a broader, 'browsing options' code. During this second cycle, moreover, certain provisional codes were discarded because they were not directly relevant to the research questions. For example, visibility of IRs and their content (both within an institutional website as well as to external search engines) had emerged as a provisional code, but it was discarded during the second cycle because it is not a property of the usability of repository user interfaces. As mentioned earlier, other studies such as that of Macgregor (2018) have focused on repository discoverability as an issue in its own right. Overall, the coding process produced 7 thematic codes that would form the basis of developing and describing a provisional set of domain-specific heuristics.

3.5 Domain-specific heuristics

3.5.1 Background and context: domain-specific heuristics

Nielsen established a well-known set of 10 usability heuristics that remain the most widely used industry standard. Nielsen's 10 usability heuristics consist of: 1) visibility of system status, 2) match between system and the real world, 3) user control and freedom, 4) consistency and standards, 5) error prevention, 6) recognition rather than recall, 7) flexibility and efficiency of use, 8) aesthetic and minimalist design, 9) help users recognise, diagnose and recover from errors, 10) help and documentation (Nielsen, 1993). While Nielsen's heuristics remain widely used, it is now over 20 years since they were developed and increasing attention has been given to developing heuristics applicable to specific domains. Nielsen himself suggested this when he stated that, 'it is possible to develop category-specific heuristics that apply to a specific class of products as a supplement to the general heuristics' (1994a, p.29). While heuristic evaluation has been shown to be effective in identifying both major and minor usability problems, a concern is that it can fail to capture domain-specific problems (Rusu *et al.*, 2010). Given this concern, it was decided to develop domain-specific heuristics as a supplement to Nielsen's heuristics, to better identify usability problems specific to IRs. As Rusu *et al.* indicate, this approach seems to have been successful in other studies, 'as demonstrated by the overlap of identified usability issues using domain specific heuristics and general heuristics' (2010, p.180).

However, at present, no consensus exists as to the most effective methodology for developing domain-specific heuristics (Hermawati and Lawson, 2016; Van Greunen and Pottas, 2011; Quiñones, Rusu and Rusu, 2018). Despite the lack of consensus on this issue, the present research adopted methods for developing domain-specific heuristics primarily as suggested by Quiñones, Rusu and Rusu (2018), but also incorporating aspects of the methods suggested by Rusu *et al.* (2010) and Van

Greunen and Pottas (2011). All three of these studies propose developing domain-specific heuristics following from the basis of a literature review and this approach was adopted here.

3.5.2 Developing domain-specific heuristics

As noted above, coding performed in relation to the literature review revealed 7 thematic codes that would be used as the basis to develop a provisional set of domain-specific heuristics. These 7 thematic codes are searching, browsing, visual design, web 2.0 features, terminology, supporting information and usage statistics. A fuller description of each theme is provided in **Table 1, below.**

Description of Feature	Provisional Heuristic
Users are provided with a range of different search options, including key word and advanced search. Search results include appropriate metadata for items. The mechanism used to order results is clear and can be amended by users.	**P1:** Search function
Users can browse in a range of different ways, including by author or content type. The different browsing options are meaningful, reflective of institutional communities such as subject discipline or faculty. Browsing is supported by a clear site hierarchy, directing users toward different types of content.	**P2:** Browsing options
The visual design is clear, aesthetically pleasing and stimulating. Links are clearly presented, and it is easy to identify links to open digital content. There is a clear visual hierarchy which conveys structure and aids navigation.	**P3:** Visual design
A range of web 2.0 features are provided, such as the as the ability to follow updates or share content. These features are highly visible and easily identifiable.	**P4:** Web 2.0 features
Natural language is employed, rather than jargon or library/systems-based terminology. Any complex or confusing terms are explained through textual or visual means.	**P5:** Terminology
Supporting information is provided regarding the nature and scope of content contained within the IR. User guidance is available for the main services/features provided by the IR.	**P6:** Supporting Information
Usage statistics are provided. Statistics are clearly and meaningfully presented. A range of filter options are provided. Users can generate and download statistics reports.	**P7**: Statistics

Table 1: description of provisional heuristics

Noting the lack of consensus on the issue of the best method of creating domain-specific heuristics, Quiñones, Rusu and Rusu (2018) propose a formal methodology for developing usability heuristics. The authors outline an 8-stage methodology, as represented in **Figure 1, below.** The methods employed in the present research were informed by the process outlined in steps 1 to 6 of this proposed methodology. Unfortunately, completion of steps 7 and 8 were precluded by the limited timeframe and resources of the current study. The authors describe that Step 7 would involve expert evaluation and user testing to establish the validity of the heuristics. Furthermore, they describe that Step 8 would involve refining the new set of heuristics based on the feedback and results obtained in

Step 7. While it was outwith the scope of this study to complete the two latter steps, it is hoped that future research will assess the validity of, and perhaps further refine, the proposed set of heuristics. Nevertheless, the methods employed herein were informed by the earlier stages of the model. For example, a literature review was conducted to determine information about the specific application domain, which is referred to as the 'exploratory stage' in Step 1 of the proposed model.

Figure 1: Quiñones, Rusu and Rusu (2018) methodology for developing usability heuristics.

Step 2 involves identifying and gathering data from relevant previous experiments that were performed by other researchers. This step corresponds to the process employed in the current study, of selecting relevant studies conducted by other researchers. Step 3, the 'descriptive stage', involves selecting and prioritising important topics of information from the data that was collected in the previous stages. This is akin to the process of thematic coding completed in the present study, to identify the most significant themes of the selected usability studies. Step 4, the 'correlational stage' is described as the stage in which the identified usability features of the specific application domain are matched with heuristics. This step was completed in the present study, wherein information represented by the seven thematic codes identified previously was used to develop a set of features, which were then mapped against provisional heuristics. The results of this step are shown in **Table 2, below.** Provisional heuristics are denoted by the nomenclature P1, P2, etc.

Provisional Heuristics	Nielsen's Heuristics	Action
P1: Search function	-	Create new heuristic
P2: Browsing options	-	Create new heuristic
P3: Visual design	N8: Flexibility and efficiency of use	Adapt the existing heuristic
P4: Web 2.0 features	-	Create new heuristic
P5: Terminology	N2: Match between system and the real world	Keep the existing heuristic
P6: Supporting information	N10: Help and documentation	Adapt the existing heuristic
P7: Statistics	-	Create new heuristic

Table 2: mapping of provisional heuristics against Nielsen's heuristics.

Once the provisional heuristics had been generated, these were then mapped against the existing general set of usability heuristics, Nielsen's usability heuristics. This method of mapping the proposed new set of heuristics against Nielsen's heuristics is similar to that employed by Rusu *et al.* (2010). The model proposed by Quiñones, Rusu and Rusu (2018) specifies that mapping against existing heuristics takes place at Step 5. During this step, the authors state that a decision should be made for each heuristic as follows: 'keep the existing heuristic without any change', 'eliminate the existing heuristic', adapt the existing heuristic' or create a new heuristic' (Quiñones, Rusu and Rusu,

2018, p.115). This step is intended to identify any areas of overlap or redundancy with respect to the general heuristics. The method was employed here with the intention to identify supplemental heuristics to Nielsen's usability heuristics. The decision was taken to supplement, rather than eliminate Nielsen's heurstics, because of a concern to avoid the pitfall of missing any issues that would be identified by general heurstics but missed by domain-specific heuristics (Hermawati and Watson, 2016). The mapping and resulting actions from this stage are outlined in **Table 2.** A single dash denotes where there was judged to be a lack of correspondence with Nielsen's heuristics.

Based on the outcome of Step 5, as shown in **Table 2**, the researcher proceeded to Step 6, which involves formally specifying the new set of usability heuristics. **Table 2** identifies where it was decided to either create a new heuristic or adapt an existing heuristic. Those of Nielsen's existing heuristics not identified to be adapted were retained, unmodified. An identifying number was attributed to each new heuristic, and a brief but concise definition of was provided. A total of 14 heuristics were included in the newly proposed set, shown below. This adheres to advice from Quiñones, Rusu and Rusu that the final number of heuristics 'be between 10 and 16' (2018, p.115). Descriptions of the unmodified general heuristics are taken directly from Nielsen (1994b). The new set of heuristics are as follows:

- **H1. Search function:** Users are provided with a range of different search options, including key word and advanced search. Search results include appropriate metadata for items. The mechanism used to order results is clear and can be amended by users.
- **H2: Browsing options:** Users can browse in a range of different ways, including by author or content type. The different browsing options are meaningful, reflective of institutional communities such as subject discipline or faculty. Browsing is supported by a clear site hierarchy, directing users toward different types of content.
- **H3: Visual design:** The visual design is clear, aesthetically pleasing and stimulating. Clutter is kept to a minimum, with irrelevant or rarely used information kept to a minimum. There is a clear visual hierarchy which conveys structure and aids navigation. Links are clearly presented, and it is easy to identify links to open visual content.
- **H4: Web 2.0 features:** A range of web 2.0 features are provided, such as the as the ability to follow updates or share content. These features are highly visible and easily identifiable.
- **H5: Terminology:** Natural language is employed, rather than jargon or library/systems/based terminology. Any complex or confusing terms are explained through textual or visual means.
- **H6: Help and supporting information:** Help and documentation is available to users to consult as problems arise. The help documentation is easy to locate and focused on specific tasks. Supporting information is provided regarding the nature and scope of content contained within the IR. User guidance is available for the main services/features provided by the IR.

- **H7: Statistics**: Usage statistics are provided. Statistics are clearly and meaningfully presented. A range of filter options are provided. Users can generate and download statistics reports.
- **H8: Visibility of system status:** The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.
- **H9: User control and freedom:** Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.
- **H10: Consistency and standards:** Users should not have to wonder whether different words, situations, or actions mean the same thing. Graphic elements and terminology should be employed consistently throughout all parts of the interface.
- **H11: Error prevention: User encounters of errors should be kept to a minimum.** Users should be provided with a confirmation message before committing to any action.
- **H12: Minimise the user's memory load by making objects, actions, and options visible.** The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.
- **H13: Flexibility and efficiency of use:** 'Accelerators', such as shortcuts or automation of actions, can be used to speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Users are able to tailor the interface so that frequent actions can be performed more quickly.
- **H14: Help users recognise, diagnose and recover from errors.** Error message should always be expressed in plain language, precisely indicate the problem, and constructively suggest a solution.

3.6 Analysing the results of the heuristic evaluation

3.6.1 Severity ratings

Nielsen (1994a) proposed using severity ratings in order to improve the explanatory power of heuristic evaluations. He suggests that severity ratings can be useful as a means to assess the relative severity of the usability problems, allowing for attention and resources to be prioritised in fixing the most severe problems. Nielsen (1994a) states that the severity of a usability problem is a combination of three factors: the frequency with which the problem occurs, the impact of the problem if it occurs and the persistence of the problem. A numerical value is applied to rate the severity of each heuristic valuation, using the five-point scale put forward by Nielsen (1994a), as presented in **Table 3.**

Severity Rating	Description
0	I don't agree that this is a usability problem at all
1	Cosmetic problem only – need not be fixed unless extra time is available on project
2	Minor usability problem – fixing this should be given low priority
3	Major usability problem – important to fix, so should be given high priority
4	Usability catastrophe – imperative to fix this before product can be released

Table 3: Nielsen's severity ratings system.

3.6.2 Evaluative approach

The set of heuristics proposed above were used to evaluate the usability of each of the HEI IR user interface. While a free-flow approach, as described above, was adopted, the 'two-pass' method was used to ensure thoroughness of the evaluation. Heuristics violations were recorded in an appropriately structured table in Excel and severity ratings assigned. A template table used to record heuristic violations for each institution is provided in **Appendix 3.** Separate tables were stored on individual tabs on an Excel worksheet, to record the violations for each individual institutional IR interface. Results were then collated and analysed in Excel, as will be discussed in greater detail below.

Section 4.0 Results

4.1 Revisiting the research questions

At this stage, it is worth revisiting the research questions (outlined in **Section 1.2**) in order to frame and structure the presentation of the results. Research question 1 has been answered in the preceding Methods section, in which a novel set of domain-specific heuristics were established. These 14 heuristics were then used to evaluate the usability of user interfaces of 18 research repositories provided by Scottish HEIs. Note that, although there are 19 HEIs in Scotland, only 18 repositories were evaluated, due to the fact that repository services for the Royal Conservatoire of Scotland (RCS) are provided by the University of St Andrews. See **Appendix 1** for a full list of the institutions considered. As mentioned above, it is hoped that the 14 new domain-specifics proposed in the present research will be tested and validated by other, expert evaluators. Similarly, it is hoped that the results of the present evaluation will prompt further comparative evaluations that will help to mitigate against the limitations of this research, which result from the subjective nature of heuristic evaluation.

Research questions 2 and 3 can be addressed by considering the results of the heuristic evaluation. Research question 2 will be addressed by considering how the repositories under evaluation performed against the set of 14 domain-specific heuristics previously identified. Research question 3 will be addressed by considering which of the 14 heuristics were violated most severely and most frequently across the 18 repositories. To identify the priority areas for improvement, analysis of the results will focus on those heuristics which received the highest number of major violations across the 18 repositories. To recap, 'major' violations are those with a severity rating of 3. The severity rating system, as developed by Nielsen, identifies major problems as those which are 'important to fix, so should be given high priority' (1994a). It is hoped that the identification of those heuristics which received the greater number of major violations will be useful to inform and focus the efforts of staff involved in repository optimisation, such as repository managers and systems developers. In his influential book *Don't Make Me Think*, Steve Krug argues in favour of focusing 'ruthlessly on fixing the most serious problems first' (2014, p.138). He argues that this ruthless focus helps to avoid a situation in which those involved in software optimisation 'opt for the low-hanging fruit' (2014, p.137), ie they prefer to address the cosmetic or minor violations which are easy to fix, rather than tackle the more pressing, significant challenge of resolving major or catastrophic issues.

4.2 Overall results

The complete set of overall results is shown in **Appendix 4.** In this section, a brief summary of the overall results will be provided in order to aid later discussion. **Table 4,** below, details the performance of each institution against usability violations (broken down to number of cosmetic, minor and major violations by institution). The data has been sorted firstly in descending order by number of major violations and then secondly in descending order by overall total number of violations. This presents a clear picture of which institutions fared worst in terms of highest number of major violations, compared against the total number of violations overall.

No.	Name	Cosmetic	Minor	Major	Overall Total
8	The University of Aberdeen	2	4	3	9
11	The Robert Gordon University (RGU)	3	2	3	8
9	Edinburgh Napier University	2	8	2	12
5	The University of the West of Scotland	2	6	2	10
7	The University of Dundee	0	8	2	10
12	Heriot-Watt University	1	5	2	8
15	Queen Margaret University, Edinburgh	2	3	2	7
18	SRUC	2	3	2	7
4	Glasgow Caledonian University	3	8	1	12
14	University of the Highlands and Islands	4	5	1	10
1	The University of Edinburgh	1	7	1	9
10	The University of Stirling	2	6	1	9
16	University of Abertay Dundee	1	6	1	8
13	The University of St Andrews	5	1	1	7
2	The University of Glasgow	4	5	0	9
6	The Open University	2	4	0	6
3	The University of Strathclyde	3	2	0	5
17	Glasgow School of Art	2	2	0	4
TOTALS:		**41**	**85**	**24**	**150**

Table 4: institutional performance by total number of usability violations.

Notably, no 'catastrophic' violations were recorded in any of the 18 repositories. This was to be expected, given that repository user interfaces presenting 'catastrophic' usability issues should not be available for interrogation. However, none of the repositories evaluated were considered to be free from violations. A total of 150 violations occurred across the 18 repositories. Of this total, a significant minority (n=24) were identified as major. The highest proportion of violations were considered to be minor (n=85). The second highest proportion of violations were considered to be cosmetic (n=41). Considered together, a total of 126 violations were considered to be either cosmetic or minor. Compared with a total number of 24 violations classed as major, this means that the evaluator found approximately 5 cosmetic or minor violations for every 1 major violation (126:24). **Figure 2,** below, provides a graphical representation of institutional performance against usability violations (broken down to number of cosmetic, minor and major violations per institution).

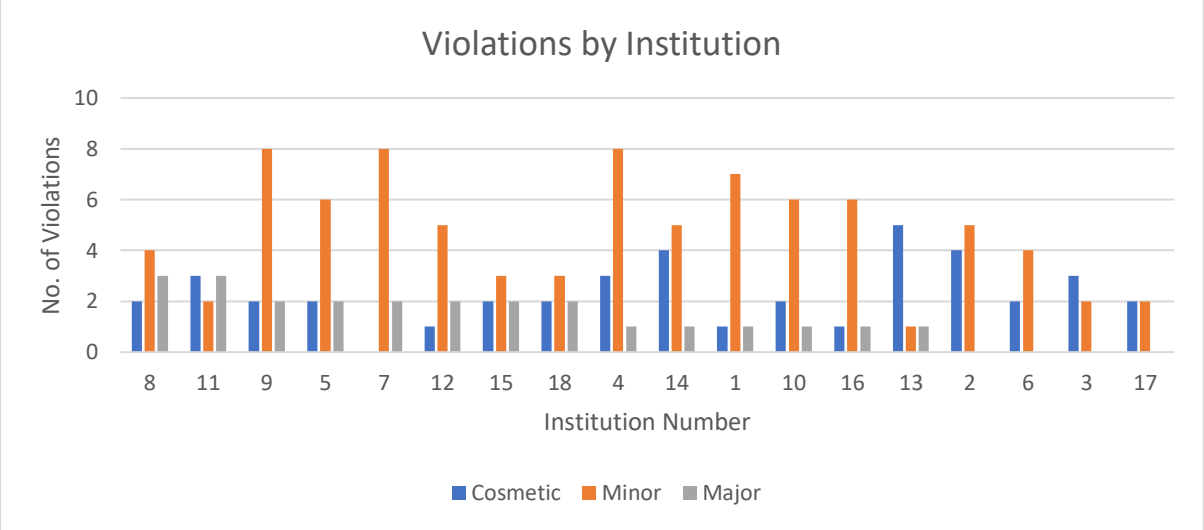

Figure 2: institutional performance by total number of usability violations.

As detailed in **Table 4** above, 4 of the evaluated repositories presented no major usability violations. In turn, 14 of the evaluated repositories did present major violations. Of the 14 repository UIs that presented major violations, 6 presented only 1 major violation, 6 presented 2 major violations, and 2 repository interfaces presented 3 major usability violations. The two repositories which presented 3 major usability violations were those of institutions 8 and 11. All 18 of the repository UIs presented minor violations. Of those 18, 10 repository UIs presented 5 or more minor violations, with 8 presenting fewer than 5 minor violations. This means that the majority of the repository UIs evaluated presented more than 5 minor violations, which indicates that repository usability could be substantially improved by addressing issues that, at least in theory, should be less onerous to resolve. However, the fact that the majority of UIs evaluated presented at least 1 major usability issue suggests some cause for concern and indicates that usability issues are a significant factor to consider in relation to user engagement with repository interfaces.

It is notable that the two repositories (institutions 8 and 11) which presented the highest number of major usability violations were both DSpace repositories. Those repositories which had no major usability violations (institutions 2, 3, 6 and 17) were all based on EPrints software. The breakdown of usability violations by software type will be presented and discussed in greater detail below.

The highest number of total violations recorded for any repository interface was 12. Institution 4 and institution 9 presented a total of 12 usability violations each. However, in both cases, the majority of these violations were either cosmetic or minor. The second highest number of violations recorded for any repository was 10. Institution 5, institution 7 and institution 14 presented a total of 10 usability violations each. Again, it is important to note that, in each of these three cases, the majority of these violations were either cosmetic or minor.

The lowest number of total violations recorded for any single institutional repository UI was 4, in the case of institution 17. Of these 4 violations, none were considered to be major. The second lowest number of total violations recorded for a single institutional repository UI was 5, in the case of institution 3. As in the previous case, it is notable that none of these 5 violations were considered to be major. Given that the highest number of violations recorded for any repository UI was 12 and the lowest was 4, this gives a range value of 8, indicating a significant difference in the overall usability of these interfaces, while bearing in mind that the majority of issues uncovered in the highest rated UIs were either cosmetic or minor.

The average number of total violations recorded across the 18 repositories was approximately 8 (150/18). The mode (most frequently occurring) number of total violations across the 18 repository UIs was 9. Considered together, the mean and mode values indicate that (albeit cosmetic or minor) usability issues are a substantial presence across Scottish HEI repository interfaces and are likely to have a significant impact on users' overall perception of their usability.

4.3 Breakdown of results by software type

As noted briefly above, the repository interfaces which presented the greatest number of major usability violations (institutions 8 and 11) were both created using DSpace software. Conversely, the 4 repository interfaces which presented no major usability violations were all created using EPrints software. This indicates a relationship between software type and usability which is worth investigating in greater detail. This relationship between software type and usability will be explored in further depth in the Discussion section, below. In total, 4 different types of software were used to create the institutional repositories for Scottish HEIs: EPrints, DSpace, Pure and Worktribe. Pure and Worktribe are examples of current research information management systems (CRISs), whereas EPrints and DSpace are examples of institutional repository platforms. EPrints and DSpace are both open source software packages that allow for extensive local customisation. This is in contrast to both Pure and Worktribe, which are both proprietary CRIS products that only enable local configuration, but not customisation. Therefore, there is greater scope for EPrints and DSpace to be customised in order to address the usability issues uncovered in the present study.

Of the 18 Scottish HEI repository platforms evaluated, 4 were created using EPrints, 6 were created using DSpace, 7 were created using Pure, and 1 was created using Worktribe. **Table 5, below** details which software is used by which institution. This is followed by **Table 6,** which summarises the total number of institutions using each software package. Information regarding which software was used to create each repository interface was obtained from OpenDOAR (OpenDOAR, n.d.)

No.	Name	Software
1	The University of Edinburgh	Pure
2	The University of Glasgow	Eprints
3	The University of Strathclyde	EPrints
4	Glasgow Caledonian University	Pure
5	The University of the West of Scotland	Pure
6	The Open University	EPrints
7	The University of Dundee	Pure
8	The University of Aberdeen	DSpace
9	Edinburgh Napier University	Worktribe
10	The University of Stirling	DSpace
11	The Robert Gordon University (RGU)	DSpace
12	Heriot-Watt University	Pure
13	The University of St Andrews	DSpace
14	University of the Highlands and Islands	Pure
15	Queen Margaret University, Edinburgh	DSpace
16	University of Abertay Dundee	Pure
17	Glasgow School of Art	EPrints
18	SRUC	DSpace

Table 5: software used by each institution to provide repository services.

Software	Total No. of Institutions Using Software
Pure	7
DSpace	6
EPrints	4
Worktribe	1

Table 6: total number of institutions using each type of software.

The breakdowns as given above in **Tables 5 and 6** indicate that 10 out of the 18 Scottish HEI repositories are based on open source repository software packages, split almost evenly between Eprints (n=4) and DSpace (n=6). However, the most widely used of any single piece of software is Pure (n=7), indicating its favoured position among CRIS packages in the Scottish HEI sector. Institution 9 is the only institution to use the Worktribe CRIS to provide a repository service.

Table 7, below shows the *average* number of violations (broken down by cosmetic, minor and major violations) for each of the software packages. See **Appendix 5** for the full breakdown of the *total* violations, by software type and heuristic. The average number of violations is shown, to aid comparison given the variation in the number of institutions utilising each software package. However, the validity of the results for Worktribe is limited due to the fact that only one institution used this software as the basis of its repository service. The data in the table is sorted firstly in descending order by average number of major violations, then secondly in descending order by average number of minor violations.

Software Type	Average No. of Cosmetic	Average No. of Minor	Average No. of Major
Worktribe	2	8	2
DSpace	3	3	2
Pure	2	6	1
Eprints	3	3	0

Table 7: average number of violations (cosmetic, minor and major) by software type.

As shown above in **Table 7,** repository UIs based on Pure presented the second-highest average number of minor violations, after Worktribe. However, Pure recorded a lower value for the average number of major violations than DSpace and Worktribe. There is no difference between the average number of minor usability violations between DSpace and Eprints. As shown above, EPrints repositories presented no major usability issues. Taking this into account, Pure repositories presented the second-lowest value for average major usability violations (n=1). The differences in usability issues encountered when evaluating repositories based on the different software packages is presented in greater detail, below.

4.3.1 Heuristic violations: Worktribe

As mentioned earlier, Worktribe is a proprietary CRIS product which enables local configuration but not customisation. Indeed, the Worktribe website highlights that the company's approach is one of '"configuration not customisation", which means that you [HEIs] can make certain choices about how our software works, but only within the framework of the system' (Worktribe, 2019). As noted above, only 1 repository interface was created using Worktribe CRIS software (institution 9). Given that only one institution of the sample evaluated used Worktribe to provide repository services, the results of the present evaluation should be treated with caution. Comparison with any future usability analysis of Worktribe-based repository interfaces would help to establish the validity of the results.

The heuristics encountered in the evaluation of this repository UI are detailed below in **Table 8.** In the case of this single institution, 1 major usability violation was encountered in relation to both heuristic 1 (search function) and heuristic 2 (browsing options). Minor usability violations were encountered equally across heuristics 3 (visual design), 6 (help and supporting documentation), 7 (statistics), 9 (user control and freedom), 11 (error prevention), 12 (make objects, actions, and options visible), 13 (flexibility and efficiency of use), and 14 (help users to recover from errors). Cosmetic violations were encountered equally across heuristics 4 (web 2.0 features) and 5 (terminology). Overall, the one Worktribe interface evaluated in the present research presented a high total number of violations, with minor violations being the most frequently occurring level of severity.

Heuristic	Cosmetic	Minor	Major	Total
H1	0	0	1	1
H2	0	0	1	1
H3	0	1	0	1
H4	1	0	0	1
H5	1	0	0	1
H6	0	1	0	1
H7	0	1	0	1
H8	0	0	0	0
H9	0	1	0	1
H10	0	0	0	0
H11	0	1	0	1
H12	0	1	0	1
H13	0	1	0	1
H14	0	1	0	1
TOTALS:	**2**	**8**	**2**	**12**

Table 8: heuristic violations encountered in the evaluation of the Worktribe-based repository.

4.3.2 Heuristic violations: DSpace

DSpace is an open source software package that enables extensive customisation. In contrast to the approach espoused by Worktribe, the DSpace website emphasises that the product is 'completely customisable to fit your needs' (DSpace, 2019). Furthermore, the DSpace website highlights that the user interface is customisable in stating that, 'you can fully customise the look and feel of your DSpace website so that it will integrate seamlessly with your own institutions' website' (DSpace, 2019). Given the extensively customisable nature of DSpace software, it is important to identify where usability issues were uncovered, in order to inform future improvements.

Table 9 below shows the number of instances each of the 14 usability heuristics was violated, specific to DSpace repository interfaces. As noted earlier in **Table 4,** the two repositories (8 and 11) which presented the highest number of major violations were both DSpace repositories. Therefore, it is useful to gain a better understanding of where these major violations occurred.

Heuristic	Cosmetic	Minor	Major	Total
H1	0	0	0	0
H2	1	5	0	6
H3	4	1	0	5
H4	1	1	4	6
H5	1	1	0	2
H6	2	2	2	6
H7	0	0	5	5
H8	0	0	0	0
H9	0	0	1	1
H10	0	1	0	1
H11	6	0	0	6
H12	1	2	0	3
H13	0	6	0	6
H14	0	0	0	0
TOTALS:	**16**	**19**	**12**	**47**

Table 9: heuristic violations encountered in the evaluation of DSpace-based repositories.

As **Table 9** shows, the greatest number (n=5) of major violations encountered in the evaluation of DSpace repositories occurred in relation to heuristic 7 (statistics). The second highest number of major usability violations (n=4) were encountered in relation to heuristic 4 (web 2.0 features). The greatest number of minor violations (n=6) encountered in the evaluation of DSpace repositories occurred in relation to heuristic 13 (flexibility and efficiency of use). An equal number of cosmetic violations (n=6) were encountered in relation to heuristic 11 (error prevention).

4.3.3 Heuristic violations: Pure

Pure is a proprietary software product developed by the Dutch information and analytics company, Elsevier. Pure is an 'out-of-the-box' software product which enables configuration, but not customisation. Indeed, the Pure website mentions that 'Pure can be configured to meet the growing requirements of your institution' (Pure, 2019). Given that the majority of Scottish HEIs use Pure to provide repository services, it is important to consider the extent to which this product presents usability issues, while bearing in mind the limited scope for local repository managers to customise the software to better reflect their users' needs.

Table 10 below shows the number of instances each of the 14 usability heuristics was violated, specific to Pure interfaces. As shown below, an equal number of major violations (n=5) was encountered in relation to heuristics 4 (web 2.0 features) and heuristic 6 (help and supporting documentation). The highest number of minor usability issues (n=7) occurred in relation to heuristic 13 (flexibility and efficiency of use). Following this, an equal number of minor usability issues (n=6) were encountered in relation to heuristics 2 (browsing options), 3 (visual design), 7 (statistics), and 12

(make options, actions and options visible). The highest number of cosmetic violations occurred in relation to heuristic 11 (error prevention).

Heuristic	Cosmetic	Minor	Major	Total
H1	0	2	0	2
H2	0	6	0	6
H3	0	6	0	6
H4	0	2	5	7
H5	2	4	0	6
H6	0	2	5	7
H7	0	6	0	6
H8	0	0	0	0
H9	2	0	0	2
H10	0	1	0	1
H11	5	2	0	7
H12	1	6	0	7
H13	0	7	0	7
H14	2	1	0	3
TOTALS:	**12**	**45**	**10**	**67**

Table 10: heuristic violations encountered in the evaluation of Pure-based repositories.

4.3.4 Heuristic violations: EPrints

EPrints is an open-source repository software package originally developed by the University of Southampton (EPrints, 2019). As the EPrints website indicates, the software is fully customisable to suit local specifications. As in the case of DSpace, the customisable nature of the software means that uncovering usability issues can help to inform subsequent developments designed to enhance the user experience.

Table 11 below, below shows the number of instances each of the 14 usability heuristics was violated, specific to EPrints repository interfaces. The violations are broken down by cosmetic and minor violations only, given that no major usability violations were encountered during the evaluation process.

Heuristic	Cosmetic	Minor	Major	Total
H1	1	0	0	1
H2	3	0	0	3
H3	1	1	0	2
H4	0	1	0	1
H5	0	1	0	1
H6	1	1	0	2
H7	0	2	0	2
H8	0	0	0	0
H9	0	0	0	0
H10	1	1	0	2
H11	3	0	0	3
H12	1	1	0	2
H13	0	3	0	3
H14	0	1	0	1
TOTALS:	**11**	**12**	**0**	**23**

Table 11: heuristic violations encountered in the evaluation of EPrints-based repositories.

As shown in **Table 11**, the greatest number of minor violations (n=3) occurred in relation to heuristic 13 (flexibility and efficiency of use). A total of 2 minor violations were encountered in relation to heuristic 7 (statistics). A total of 3 cosmetic violations were encountered in relation to heuristic 2 (browsing options). The same number (n=3) of cosmetic violations occurred in relation to heuristic 11 (error prevention).

4.4 Breakdown of results by institution type

As noted earlier in section 3, Scotland's higher education sector possesses institutions of a range of different types and origins. Taking this into account, the results of the present study can be analysed to assess the variation of the usability of IR user interfaces by type of institution. As noted in section 3, The Scottish Parliament classifies Scottish HEIs into 6 different types. The breakdown of institution by type is shown in **Table 12**. Furthermore, full contextual information in relation to the Scottish HEI institutions, including institution number, size and type, is provided in **Appendix 1**.

Type of Institution	Total No. Institutions of This Type
Post - 1992	6
Ancient universities	4
Chartered universities	4
Specialist institutions	3 (including the RCS)
The Open University	1
Partnership of colleges	1

Table 12: breakdown of total no. of institutions by type of institution.

Post-1992 universities represent the single largest number of institutions, with 6 included in this category. Ancient universities and chartered universities both include 4 institutions. Specialist institutions represents the two institutions which have their own repositories. Repository services for the specialist institution, the Royal Conservatoire of Scotland (RCS) are provided by the University of St. Andrew's. Partnership of colleges and the Open University each include only a single institution.

Table 13 below shows the average number of usability violations (broken down by cosmetic, minor, and major violations) by institution type. To aid interpretation, the same data is also presented graphically in **Figure 3** below. The average value of violations, rather than the sum, is shown, to better aid comparison given the variation in the number of each different type of institution. The data in the table has been sorted firstly in descending order by average number of major violations and then secondly in descending order by average number of minor violations.

Institution Type	Average of Cosmetic	Average of Minor	Average of Major
Post - 1992	2	6	2
Chartered universities	2	5	1
Ancient universities	3	4	1
Partnership of colleges	4	5	1
Specialist institutions	2	2	1
The Open University	2	4	0

Table 13: average no. of heuristic violations (cosmetic, minor and major) by type of institution.

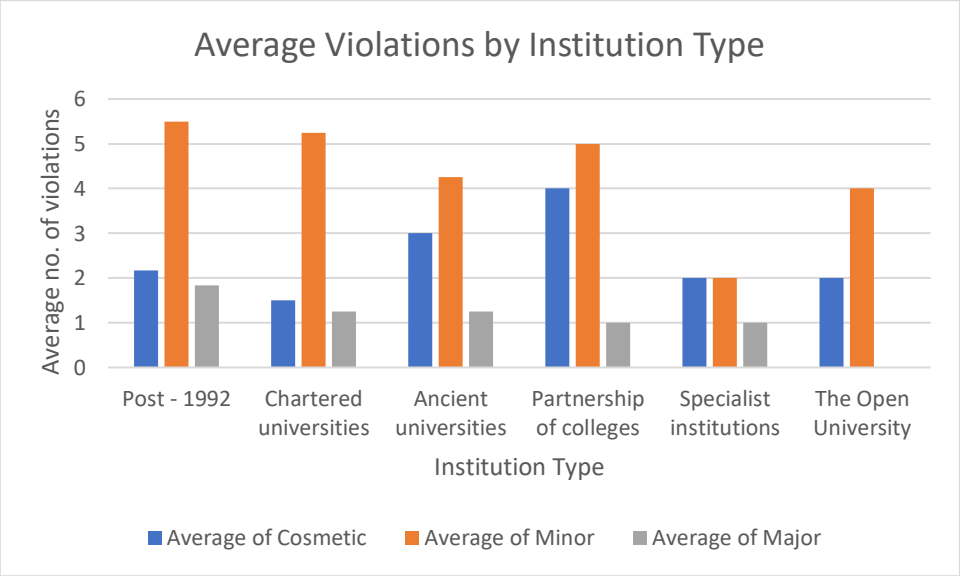

Figure 3: average no. of heuristic violations (cosmetic, minor and major) by type of institution.

As **Table 13** and **Figure 3** show, there is no significant difference in the average number of major usability violations encountered across the different types of institution. The Open University is the exception to this, but no conclusions can be drawn here, given that only one institution is represented by this category. Similarly, the variation evident in the average number of cosmetic and

minor violations encountered in the repository UIs of specialist institutions versus all other institution types cannot serve as the basis for any conclusions regarding their usability, given the small sample size (n=2).

4.5 Priority areas for improvement

Returning now to research question 3, the results of the heuristic evaluations can be used to identify the priority areas for improvement in relation to the usability of Scottish HEI repository interfaces. As was discussed in section 3, the severity ratings developed by Nielsen enhance the explanatory power of heuristic evaluations, as they enable the most serious usability issues to be easily identified. Taking this into consideration, the results of the present study can be analysed to identify which heuristics were violated with the greatest frequency and severity, across the 18 repository interfaces that were evaluated. It is hoped that identifying the heuristics which were violated with the greatest frequency and severity can be useful in informing subsequent system developments and allow the most serious problems to be prioritised for resolution. To facilitate this, **Table 14** below summarises the number of instances of violation (broken down by cosmetic, minor and major) in relation to each of the 14 domain-specific heuristics. A full breakdown of heuristic violations by institution is provided in **Appendix 4** and a full breakdown of heuristic violations by software is provided in **Appendix 5**. To aid interpretation, the summarised data is also represented graphically in **Figure 4, below.**

Heuristic	Cosmetic Problems	Minor Problems	Major Problems	Total Problems
H1	1	2	1	4
H2	4	11	1	16
H3	5	9	0	14
H4	2	4	9	15
H5	4	6	0	10
H6	3	6	7	16
H7	0	9	5	14
H8	0	0	0	0
H9	3	1	1	5
H10	0	3	0	3
H11	15	3	0	18
H12	2	10	0	12
H13	0	18	0	18
H14	2	3	0	4
TOTALS:	**41**	**85**	**24**	**150**

Table 14: total violations by heuristic (cosmetic, minor, major).

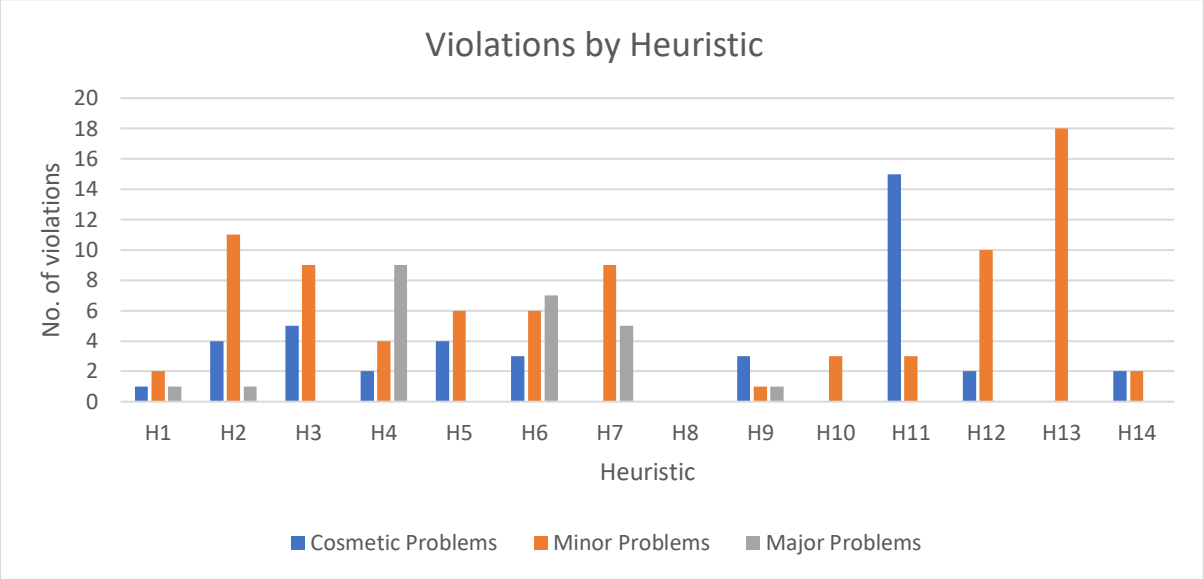

Figure 4: total violations by heuristic (cosmetic, minor, major).

4.5.1 Major violations

As **Table 14** shows, major violations occur across 6 heuristics (heuristics 1, 2, 4, 6, 7 and 9). The greatest number of instances (n=9) of a major violation of a single heuristic occurs in relation to heuristic 4 (web 2.0 features). The occurrences of the major violation of heuristic 4 are distributed between Pure (n=5) and DSpace (n=4) software packages only. As mentioned earlier, the full breakdown of heuristic violations by software type is provided in **Appendix 5**. The distribution of the major violations of heuristic 4 suggests that the functionality and presentation of web 2.0 features is a usability issue common to both Pure and DSpace repositories. However, as noted above, the open source nature of DSpace software facilitates a greater degree of customisation than is possible to achieve with Pure. Therefore, the prevalent major violation of heuristic 4 across the majority of DSpace repositories (4 out of 6) suggests that this issue has not been sufficiently addressed by any extant local customisations.

Figure 5 below, highlights the contrast in the presentation and functionality of web 2.0 features that was encountered during the heuristic evaluation of repository interfaces. The image at the top of **Figure 5** shows an example of a major violation of heuristic 4 which was encountered during the evaluation of the DSpace-based repository provided by institution 11. The only web 2.0 features provided are RSS feed options. The icons linking to RSS feed options are not visible to the user, as they are hidden at the bottom right-hand corner of the repository homepage. In contrast, the image below shows an example of good practice, encountered in the evaluation of the EPrints-based repository provided by institution 3. A good range of web 2.0 features are provided and are displayed prominently on the repository homepage.

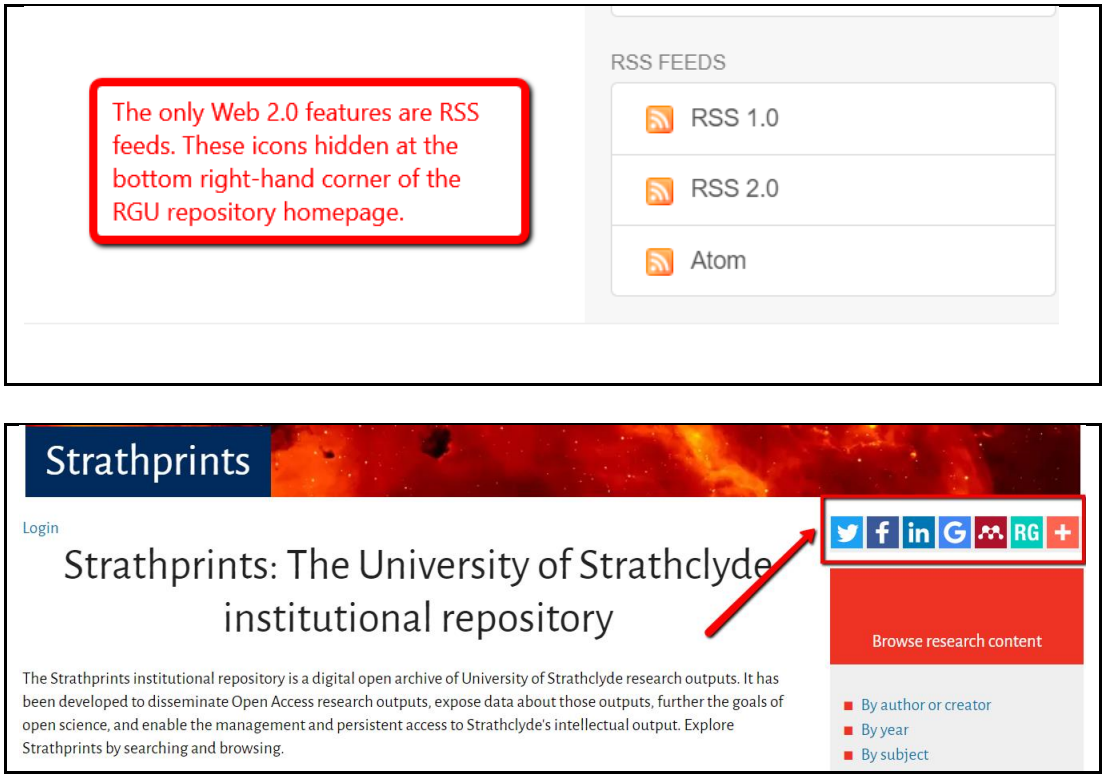

Figure 5: screenshots illustrating provision of web 2.0 features.

The second highest number of instances (n=7) of a major violation of an individual heuristic occurs in relation to heuristic 6 (help and supporting information). The majority instances (n=5) of the major violation of heuristic 6 were encountered in the evaluation of Pure user interfaces, with a minority of 2 major violations of this heuristic being encountered in the evaluation of DSpace interfaces. This suggests that the availability and presentation of help and supporting information is an issue most prevalent within Pure-based repositories. **Figure 6 below** highlights the contrast in availability and presentation of Help and supporting documentation (heuristic 6) encountered across the evaluation of the Scottish HEI repositories.

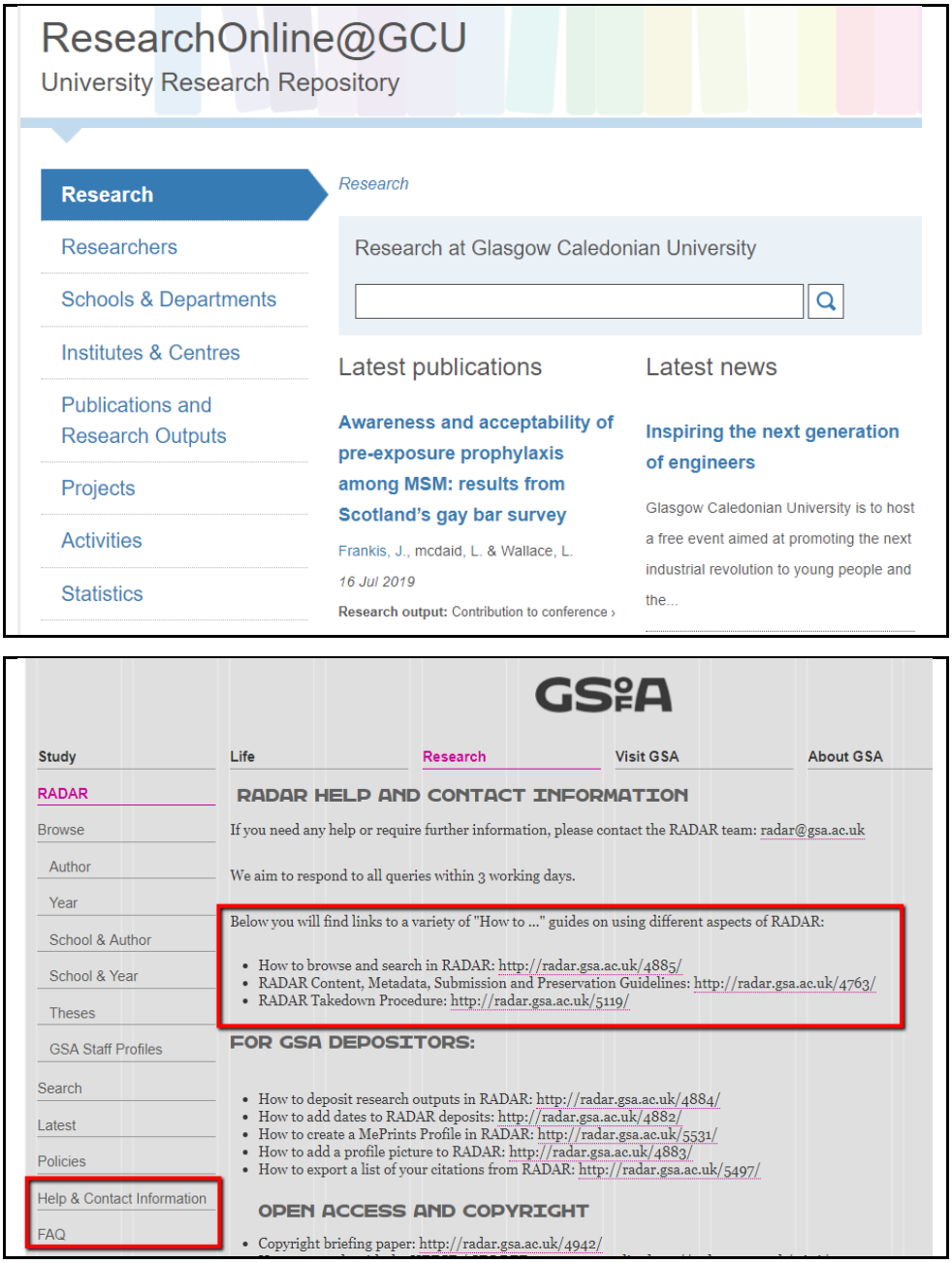

Figure 6: screenshots illustrating provision of help and supporting documentation.

The image at the top of **Figure 6** shows an instance of the major violation of heuristic 6. The image shows the homepage of the Pure-based repository provided by institution 4. No help or supporting documentation is available for the user. Any 'help' option is conspicuous by its absence from the menu options presented to the user in the menu-bar on the left-hand side of the homepage. Despite searching across the interface, the researcher could not locate any help or supporting documentation. This is in contrast to the example of good practice presented in the image below. This image shows the 'Help and Contact Information' page of the EPrints-based repository provided by institution 17. Both 'Help & Contact Information' and 'FAQs' are available as menu options which are accessible across all pages of the repository website. The menu options are clearly presented. The

scope of the Help information available via the repository of institution 17 is extensive, as highlighted in the image above which shows the 'How to' guides available to users.

Following heuristics 4 and 6, heuristic 7 (statistics), encountered major violations on a total of 5 occasions. All 5 of the major violations of heuristic 7 occurred in the evaluation of DSpace interfaces, suggesting that statistics presents a particular usability issue with respect to DSpace repository interfaces. **Figure 7 below** highlights the contrast in availability and presentation of usage statistics (heuristic 7) encountered across the evaluation of the Scottish HEI repositories.

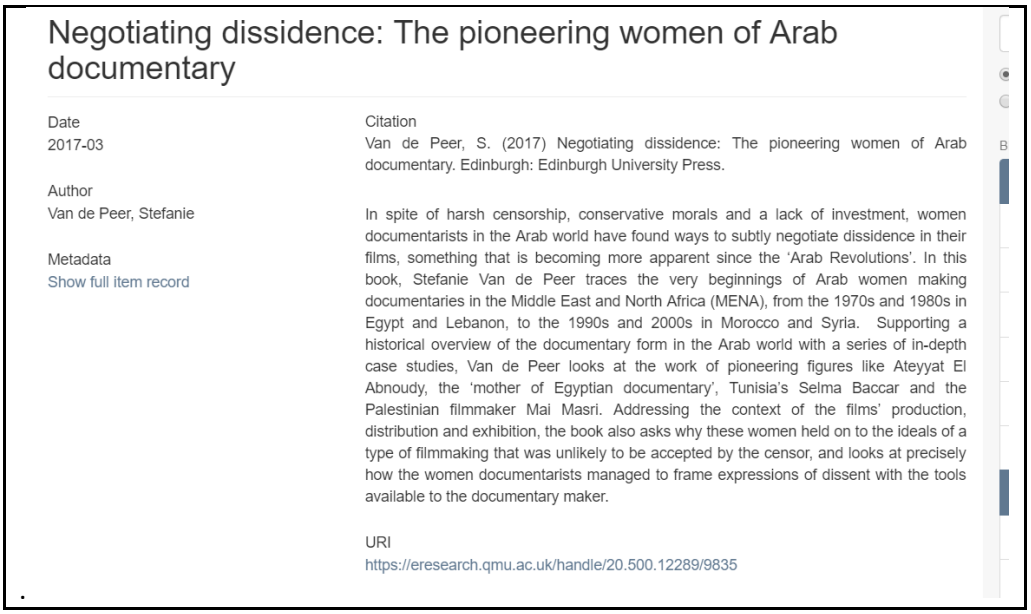

Figure 7: screenshots illustrating the provision of usage statitsics.

The first image in the above figure is a screenshot taken of an individual item record from the DSpace-based repository provided by institution 15. As is evident from the screenshot, no usage statistics are available at the individual item record level. Nor are usage statistics available at any higher level, ie at the level of research school or department, or the repository overall. The image at the bottom of **Figure 7** shows the usage statistics available via the EPrints-based institutional repository provided by institution 3. As shown, a range of different statistical information is provided. The user is able to generate, filter and download reports. Moreover, usage statistics are available at the level of individual items or authors.

The remaining 3 heuristics which encountered major violations were heuristics 1, 2 and 9, which were each violated once. The major violation of heuristics 1 and 2 were both encountered during the evaluation of institution 9's repository interface, which was created using Worktribe. The major violation of heuristic 9 was encountered during the evaluation of institution 9's repository interface, which was created using DSpace. Heuristics 3, 5, 8, 10, 11, 12, 13 and 14 presented no major usability issues across the 18 repository interfaces that were evaluated. The results allow the identification of heuristics 4, 6 and 7 as the priority areas for the improvement of interface usability among Scottish HEI repositories.

4.6 Summary of results

Overall, the results allow identification of the most pressing usability issues, in terms of frequency and severity. As noted above, the most frequently occurring of the major usability violations were incurred in relation to heuristics 4, 6, and 7. Following this, heuristics 1, 2 and 9 each incurred one major violation across the 18 repository interfaces. In light of these results, heuristics 4, 6 and 7 can be identified as the priority areas for improvement of the repository UIs provided by Scottish HEIs. In the event that all the major issues have been resolved, the most frequently occurring minor usability violations should be addressed next. The results show that heuristics 13 (flexibility and efficiency of use), 2 (browsing options), 12 (make objects, actions and options visible), 3 (visual design) and then 5 (terminology) should be prioritised for resolution, once all of the major usability issues have been resolved.

Section 5.0 – Discussion of Results

5.1 Discussion of overall results

Overall, the results revealed that usability issues are a significant presence across the user interfaces of Scottish HEI institutional repositories. As noted above, usability issues were common across all 18 of the Scottish HEI repository user interfaces that were evaluated. Only 4 out of the 18 repository UIs evaluated presented no major usability violations. Each of the 18 repository UIs evaluated presented minor violations, leading to a high total number of minor violations (n=85) encountered in the evaluation of the entire sample. While the greatest proportion of the usability issues uncovered across the sample were minor or cosmetic, a significant minority (n=24) of the usability violations were identified as major. Taken together, the high overall number of usability violations as well as the significant number of major usability issues demonstrates that usability issues are an important factor to consider in relation to the user experience of and engagement with institutional repositories provided by Scottish HEIs.

In this respect, the results of the present study support Tay's assertion that institutional repositories too often 'tend to offer poor user experience' (2017, p.12). Tay argues that the poor user experience offered by many IRs are one of the main reasons why researchers avoid them (2017). Poor user experience has serious implications for user uptake of and engagement with IRs. As discussed in Section 1, Davis' (1989) technology acceptance model posits that *perceived ease of use* is a key factor affecting user acceptance and update of systems. In short, users are more likely to accept and engage with systems that they find it easy to interact with. Thong, Hong and Tam (2002) applied Davis' technology acceptance model to analyse the usability of digital libraries. The results of their study showed that interface characteristics are a significant determinant of *perceived ease of use*. Applying this insight to the present analysis, the frequency and severity of the usability issues uncovered in relation to repository UIs is likely to have a significant impact on the *perceived ease of use* of institutional repositories, which, in turn, is likely to impact negatively on user uptake and engagement. In this respect, the results highlight the importance of considering usability issues when assessing the reasons for use of non-use of institutional repositories.

Most of the repositories in the sample evaluated in the present study have been established since the first decade of the 21st century (OpenDOAR, n.d.). Taking this into consideration, the persistence of unresolved usability issues suggests that sufficient attention to this issue has hitherto been lacking. It is hoped that the present study will help to draw attention to this issue and highlight the issue of usability as a significant factor in understanding user engagement with repositories.

5.2 Discussion of breakdown of results by software type

As noted in the previous section, the distribution of usability issues encountered in the evaluation of the 4 different software packages used by Scottish HEIs to provide repository services indicates a relationship between software type and usability. To recap, the repository interfaces which presented the greatest number of usability violations (institutions 8 and 11) were both created using DSpace software. In contrast, the 4 repository interfaces (of institutions 2, 3, 6 and 17) which presented no major usability violations were all created using EPrints software. Furthermore, while Pure presented a slightly lower average number of major usability violations (see **Table 7**) than DSpace and Worktribe, it had a higher average for minor usability violations than DSpace and EPrints. The results (see **Appendix 5**) show that Pure presented a substantially greater total of heuristic violations overall (including cosmetic, minor and major violations) than any other software package (discounting Worktribe, which is used by only 1 institution).

As discussed previously, the 4 different software packages used by Scottish HEIs to provide repository services vary in the extent to which they support local customisation. EPrints and DSpace are both open source repository software packages that allow for extensive local customisation. In contrast, Pure and Worktribe are CRIS platforms which have extended 'front-end' functionality to support repository services. As highlighted in the preceding section, both Pure and Worktribe support a degree of local configuration, but not customisation.

Although in recent years there has been a trend towards the merging of repository and CRIS functionality (de Castro, Shearer and Summann, 2014), it is useful to consider how the different origins of both platforms have left their mark on how they present themselves to users, via the outward-facing interface. CRISs originally evolved to collect a wide range of metadata about diverse aspects of the research activity carried out at an institution. This information was used to support users in recording and reporting on various aspects of the research process, including financial and HR information typically used by institutional research offices (de Castro, Shearer and Summann, 2014). IRs, on the other hand, 'evolved as part of the open access movement and aim to collect and provide free access to the research outputs created at the institutions (de Castro, 2014, p.40). To summarise, CRISs emerged from an inward-facing position, whereas IRs were developed as outward-facing platforms to support the dissemination of research to the wider scholarly community. Although the functionality of CRISs and IRs has merged to such an extent that 'we now have repositories acting as CRISs, CRISs acting as repositories and CRISs and IRs working together through systematic data exchange' (de Castro, Shearer and Summann, 2014), it is useful to bear in mind the different origins of both platforms when assessing the usability issues which they present.

Taking into consideration the 'inward-facing' origins of CRISs, the fact the results indicate that Pure presents the highest total number of usability violations overall is not surprising. Indeed, this is further reflected in the nature of the heuristic violations that were encountered in the evaluation of Pure-based repositories (see **Table 10**). Across the 7 institutions that used Pure, an equal number of major violations (n=5) were encountered in relation to heuristics 4 (web 2.0 features) and 6 (help and supporting documentation). These are both areas of functionality that support the engagement of scholars and information seekers, rather than internal professional services or library staff. This suggests that these two groups have been overlooked by software developers and repository managers when designing and configuring the software. Given that Pure is the most widely used software package among Scottish HEIs, it is important to recognise the areas in which usability could be enhanced to support an improved user experience. That the 2 most prevalent major heuristic violations occurred across the majority of Pure-based repositories (see **Appendix 5**) indicates that these usability issues have not been adequately resolved by any local configurations.

Similarly, the heuristic violations encountered in the evaluation of the single Worktribe-based repository interface reflects the 'inward-facing' nature of the platform's development, with major violations encountered in relation to heuristic 1 (search function) and heuristic 2 (browse options). Major heuristic violations in these 2 areas reveal a lack of functionality to support the successful engagement of users as information seekers. However, as only 1 institution used the Worktribe CRIS as the basis of their repository service, future research is needed in order to assess the wider validity of these results.

In contrast to the 2 CRIS software packages, both EPrints and DSpace are open source software packages that allow for extensive local customisation. Taking into consideration the 'outward-facing' origins of repository software, it is not surprising that the evaluation of the 4 repositories created using EPrints software presented no major usability violations. The highest number of minor violations (n=4) encountered in the evaluation of EPrints-based repositories (see **Table 11**) occurred in relation to heuristic 13 (flexibility and efficiency of use). However, minor violations of heuristic 13 occurred uniformly across all of the 18 repository interfaces included in the sample. Generally, the evaluator noted the lack of functionality across all 18 of the repositories to enable users to tailor the interface so that frequent actions can be performed more quickly. The comprehensive nature of the violation of heuristic 13 across all 18 repository interfaces indicates the significance of this usability issue across all platforms and shows that this issue is not uniquely characteristic of EPrints software. Overall, the lack of major usability issues encountered in the evaluation of EPrints-based repositories reflects both the 'outward-facing' origins of the platform, as well as the ability of any usability issues to be resolved via local customisation.

Like EPrints, DSpace software is fully customisable. However, in contrast to EPrints, evaluation of the 6 DSpace-based repositories uncovered a high total number of violations (see **Appendix 5**). Moreover, DSpace-based repositories presented the highest average number of major violations (with the exception of Worktribe, which is used by only 1 institution). The usability issues uncovered in the evaluation of the DSpace-based repositories reflects findings of earlier studies such as Davis and Connolly (2007), which highlighted usability issues as a key contributing factor to the non-use of Cornell University's DSpace-based repository. However, the results of the present study contrast with the findings of Jihyun Kim's (2005) study, in which testing of the Australian National University's revealed a user preference for DSpace rather than EPrints. The contrast in the results between the present study and Kim's study may be at least partly attributable to updates to functionality and design made to the respective platforms since the earlier analysis was conducted.

The high total number of heuristic violations encountered across the evaluation of the 6 repositories that use DSpace is of particular concern, considering that the software is fully customisable (see **Appendix 5**). The 2 areas in which major heuristic violations are most prevalent across DSpace repositories (see **Table 9**) occurred in relation to heuristics 4 (web 2.0 features) and heuristic 7 (statistics). These are both areas in which DSpace has the functionality to support local customisation.

Bankier and Gleason's report *Institutional Repository Software Comparison* (2014) compared the functionality of repository platforms including Digital Commons, DSpace, EPrints and Fedora. In this report, Bankier and Gleason (2014) explore the functionality of these platforms in relation to areas including social features and notifications (web 2.0 features) and reporting (including repository usage statistics). The authors identify that DSpace has the functionality to support add-on services and customisation in relation to the areas of social features and notifications, as well as reporting. The fact that these 2 areas emerge as the most prevalent sources of major usability violations with respect to DSpace repositories indicates that these issues have not been sufficiently resolved by any local customisations. Indeed, the fact that violations in respect to heuristics 4 and 7 occur in the majority of DSpace-based repositories (see **Appendix 5**) suggests a lack of any local customisation to address these usability issues. In contrast to EPrints, the high total number of usability issues encountered in the evaluation of DSpace-based repositories poorly reflects the 'outward-facing' nature of its origins and indicates that local customisation could be used to greater effect to address key usability issues.

5.3 Discussion of breakdown of results by institution type

Overall, the analysis of the distribution of heuristic evaluation reveals no significant difference in the number of usability violations encountered with respect to type of institution. This suggests that no

significant relationship exists between type of institution and IR interface usability. This is to be expected, considering the range of different types of software used by each institution type, as well as the varying degrees of local configuration or customisation. For example, the post-1992 category represents the largest number of universities, which use 3 different software packages. The use of different types of software, as well as differences in how the software has been developed, helps to explain the variance in terms of usability *within* each category of institution type. For example, within the set of post-1992 institutions, the highest total number of usability violations is 12 (institutions 4 and 9), whereas the lowest number of total violations is 7 (institution 15). These results suggest that software type, combined with local customisation and development, is a more important factor in determining IR interface usability than type of institution.

5.4 Discussion of priority areas for improvement

The results of the present research identified that heuristics 4 (web 2.0), heuristic 6 (help and supporting documentation) and heuristic 7 (usage statistics) are the priority areas for improvement in relation to the usability of Scottish HEI repository interfaces. As discussed in the preceding section, the identification of these as the priority areas for improvement is based on an analysis of which heuristic violations occurred with the greatest severity and frequency across all 18 repository interfaces.

The emergence of heuristic 4 (web 2.0 features) as a key usability issue supports the findings of previous studies that have identified this as a significant usability issue for institutional repositories. For example, the persona-based repository usability evaluation conducted by Maness, Miaskiewicz and Sumner (2008) highlighted that users would like to be able to easily share content, including pre-publications, and engage others via the platform to solicit feedback and foster collaboration. Similarly, St. Jean *et al.*'s (2011) interview-based research on repository usability identified the ability to use the platform to share content and identify potential networking and collaborative opportunities as a key concern for users. More recently, Aljohani and Blustein's (2015) focus group-based analysis of Dalhousie University's research repository revealed the importance of web 2.0 functionality to users. Participants in this study expressed their desire to receive email notifications when new content in an area of interest is uploaded and to be able to comment on and share content.

The necessity of repositories supporting functionality in the area of web 2.0 features is rendered apparent by Ann Michael's (2019) recent interviews with expert stakeholders on the issue of the future of scholarly publishing. In this blog post, a vision is articulated of a future for the publishing of scholarly outputs which is much more fluid and interactive than the present scenario. Rick Anderson argues that 'the boundaries of the 'article' have definitely become more porous over

the past decade or so, and probably will become more so as time goes on' (Anderson, quoted in Michael, 2019). Supporting this view, Jasmine Wallace argues that scholarly communications will 'become shapeless and more fluid […] blurring the lines completely between collaboration and discoverability' (Wallace, quoted in Michael, 2019). It is envisaged that this more fluid environment will better reflect the needs of researchers, who wish to be able to comment on and share scholarly work throughout each stage of its production.

The necessity of repositories supporting users' ability to comment on and share content is recognised by the Confederation of Open Access Repositories (COAR), which has drawn up a list of recommended behaviours for 'next generation repositories' based on user stories (COAR, n.d.). COAR recommends that next generation repositories should support interacting with resources, in relation to annotation, commenting and review. COAR cite several stories in support of this recommendation, including one user's comment that 'I want to be able to comment or review the work of my colleagues and have those reviews (and reviewers) publicly available to other readers' (COAR, n.d.). In developing functionality to support such interactive user engagement, 'repositories can begin to reposition themselves to the centre of scholarly communication and promote discussion and collaborative work' (COAR, n.d.).

The identification of heuristic 6 (help and supporting information) as a key usability issue also supports the findings of previous research. Davis and Connolly (2007) identified uncertainty over the nature and scope of the material contained within an institutional repository as one of the main reasons for academic non-engagement. In this respect, providing concise supporting information regarding the nature and scope of content, which is accessible from the repository homepage, can enhance user engagement. Davis and Connolly's findings are reflected in St. Jean *et al.*'s (2011) study, in which focus group participants expressed uncertainty and confusion over what an institutional repository actually *is*, as well as a lack of knowledge about the type and quality of the materials that they contain. Again, providing users with clear, concise help documentation and supporting information can play an important role in supporting user engagement.

The results of the present study indicate the inconsistent approach to the provision of help and supporting documentation in the case of Scottish HEI repositories. In some cases, such as that of institution 9, help and supporting documentation is provided but is aimed exclusively at depositing authors, neglecting to provide support for users as information seekers. In other instances, such as in the cases of institutions 1 and institution 14, extensive help and supporting documentation is provided, but is not accessible via the repository. Instead, the user must locate this information indirectly by searching each institution's Research Office website. In the worst cases (institutions 4, 5, 7, 8, 12, 15 and 16), no help or supporting documentation was available. An example of best practice

is that of institution 17, where help and supporting documentation, including FAQs, is accessible across the repository interface. The documentation is aimed at both users as depositors and users as information seekers and provides guidance on key issues such as copyright and REF policy compliance. While the severity and frequency of the violation of heuristic 6 indicates that this is a priority area to be addressed, it is possible to provide improvements in this area across all software platforms with minimal technical difficulty.

Furthermore, the emergence of heuristic 7 (usage statistics) as a key usability issue in the results of the present evaluation reflects Aljohani and Blustein's (2015) conclusion that repository users would find it beneficial to be able to view and download accurate, reliable statistics in relation to the usage of repository content. The results of the present evaluation revealed inconsistencies in the provision of usage statistics. Particularly in the case of DSpace-based repositories (see **Appendix 5),** usage statistics were simply not provided, neither at the level of the repository as a whole, research units, or for individual outputs. However, Bankier and Gleason's (2014) report indicates that this is an area in which DSpace has functionality that could be exploited. The lack of developed local functionality in this area reveals an inattention to this issue on the part of repository managers and systems developers. External organisations such as IRUS-UK provide a service that aggregates usage statistics for repositories across the UK (IRUS-UK, 2019). However, it is important for users to be able to access and download clear, reliable usage statistics themselves while using the repository, rather than this information being provided to them via an intermediary.

The provision of clear, reliable usage statistics can help promote academic engagement with repositories, by providing scholars with valuable insight into how their work is being used. COAR includes 'exposing standardized usage metrics' as one of the recommended future behaviours for next generation repositories (COAR, n.d.). In support of this recommendation, they cite the comments of one user that 'I want to know how often my paper, dataset or other resource is being used, and to be able to compare that with other papers of my peers' (COAR, n.d.). To enable such cross-comparison, it is essential that 'methodologies for measuring usage must be standardized across repositories and repository platforms' (COAR, n.d.). The use of standardized metrics should be supported by clear and consistent presentation of statistics to users, to facilitate ease of interpretation. Repositories which host multiple copies of the same article should be able to 'share and sum their separate usage metrics, which in turn will let the author (and other users) see the overall, aggregate statistics' (COAR, n.d.). Additionally, improvements to usability in relation to heuristic 7 can be enhanced by improvements in the area of heuristic 6, as clear guidance and supporting information can help users to interpret and understand any available usage statistics. Overall, improvements to the consistency and presentation

of usage statistics can enhance repository usability and help to demonstrate the value of the repository to users and other stakeholders (COAR, n.d.).

5.5 Discussion of summary of results

Overall, analysis of the results has enabled the identification of the most critical usability issues. The results resonate with the findings of earlier studies as discussed above, which similarly identify the areas of web 2.0 functionality, help and supporting documentation and usage statistics as key factors impacting on the usability of institutional repositories. Analysis of the results also enabled the most frequently occurring minor heuristic violations to be identified. To recap, these were heuristics 13 (flexibility and efficiency of use), 2 (browsing options), 12 (make objects, actions and options visible), 3 (visual design) and 5 (terminology). As in the case of the major heuristic violations, the identified minor heuristic violations resonate with the findings of earlier studies which highlight flexibility, browsability, visibility of options, visual design and terminology as important usability issues in relation to repositories (Kim, 2005; Luca and Naryan, 2016; St. Jean *et al.*, 2011).

Section 6.0 – Recommendations

6.1 Recommendations to improve the usability of Scottish HEI institutional repositories

It is recommended that:

- **Recommendation 1:** improvements to the usability of Scottish HEI repository interfaces should be targeted in relation to the identified priority areas for improvement: heuristics 4 (web 2.0), heuristic 6 (help and supporting documentation) and heuristic 7 (usage statistics).

These are the 3 areas in which major violations occurred with the greatest frequency across the 18 repository interfaces evaluated. In respect to these heuristics, it is recommended that:

- **Recommendation 2:** repository managers or systems developers should exploit the available functionality of the repository software/CRIS front-end to provide clear and consistently presented web 2.0 features, help and supporting information and usage statistics.

As discussed above, EPrints and DSpace are both fully customisable and have the necessary functionality to support improvements in each of these 3 areas. In the case of Pure and Worktribe-based repositories, implementation of improvements will be constrained by the fact that these software systems only support local configuration, not customisation. As only 1 institution used Worktribe to provide its repository service, it is not possible to derive from the results any understanding as to how far local configuration can be used to make improvements in respect to the 3 key areas identified above.

However, variation in the severity of these heuristic violations *within* Pure-based repository interfaces indicates that local configuration can be utilised to address, to a certain extent, usability issues in these key areas. For example, institution 4 provides a range of web 2.0 options to the user once he/she has selected an individual research output. A minor severity rating was recorded in relation to H4 for this institution, as the evaluator noted that the available web 2.0 options could be more prominently featured via the repository homepage and also on the search results listing page. However, as noted in Section 5, major violations of heuristic 4 occurred across the majority of Pure-based repositories, indicating that this issue is yet to be adequately resolved. Yet, as the example of institution 4 suggests, local configuration can be used to make improvements in this area. With respect to heuristic 4 (web 2.0 features), it is recommended that:

- **Recommendation 3:** improvements are designed to ensure that a range of web 2.0 features should be provided, including the ability to follow updates and share content. These features should be highly visible and accessible across the repository interface.

The results of the evaluation reveal that local configuration and resource development can also be used to support improvements in relation to help and supporting documentation and usage statistics. Improvements in relation to heuristic 6 (help and supporting documentation) should not be constrained by technical limitations. With respect to heuristic 6, it is recommended that:

- **Recommendation 4:** help and documentation should be available to users to consult as problems arise. The help documentation should be easily accessible across the repository interface. The help and supporting documentation should be aimed at users both as authors and information seekers and should provide clear guidance on specific tasks, focussing on the main services/features provided by the IR.

Recommendation 4 would help to address violations of heuristic 6 as encountered in the evaluation of the Pure-based repository of institution 14, in which extensive help and supporting documentation was available via the institution's Research Office website but was not linked to via the repository interface.

Furthermore, results of the evaluation revealed that Pure-based repository interfaces have functionality to support a range of clear, meaningful usage statistics. Violations in respect to this heuristic were typically due to inconsistency of provision, ie statistics were available for some outputs but not others. Moreover, as in the case of institution 5, statistics were available at the level of individual research output but not at any higher level such as school or research unit. Better consistency in the provision and presentation of usage statistics within Pure-based repositories could help to improve performance in this area. As noted in the preceding Discussion section, improvements in the area of heuristic 6 (help and supporting documentation) could also impact positively on performance in relation to heuristic 7 (usage statistics), as users would be provided with better guidance and support to make best use of any statistics provided. With respect to heuristic 7 (usage statistics) it is recommended that:

- **Recommendation 5:** a range of usage statistics should be provided. The provision of usage statistics should be consistent at all levels, ie at the level of research output or organisational unit. Statistics should be clearly and meaningfully presented, and a range of filter options should be provided. Users should be provided with the option to generate and download reports.

To re-iterate, repository managers/systems developers exploit the available functionality of the repository/CRIS software to the full in order to address the violations in respect to these three key areas. As highlighted in Section 5, the emergence of these 3 heuristics as a critical focus of repository

usability reflects the findings of earlier studies, in which similar concerns were identified. Given these findings, it is recommended that

- **Recommendation 6:** repository managers should consider using fully customisable, open source software packages (such as EPrints and DSpace) in order to maximise the potential to address usability issues and fulfil local user needs.

In the cases of institutions which use non-customisable software such as Pure and Worktribe, it is recommended that

- **Recommendation 7:** local configuration should be used to the fullest extent possible in order to address the key usability issues identified.

Furthermore, in the event that all of the major usability issues have been resolved, it is recommended that

- **Recommendation 8:** repository managers/systems developers should target improvements in relation to the most frequently occurring minor violations: heuristics 13 (flexibility and efficiency of use), 2 (browsing options), 12 (make objects, actions and options visible), 3 (visual design) and 5 (terminology).

The above most frequently occurring minor violations should be targeted for improvement only after all of the major usability issues have been resolved. This will ensure that the most significant problems are addressed first, enabling the greatest improvement to the user experience.

6.2 Limitations and recommendations for future research

As noted in Section 3, there is a better possibility of uncovering the full range of usability issues if several evaluators are used. Nielsen (1994a) recommends the use of between 3 and 5 evaluators, to optimise discovery of the usability issues. However, only one evaluator was available for the present study. Therefore, one recommendation for future research is that:

- **Recommendation 9:** further heuristic evaluations of Scottish HEI user interfaces should be performed using multiple evaluators.

Furthermore, another limitation of the present research is the limited experience of the evaluator. Nielsen (1992) demonstrated that evaluators possessing a greater level of expertise uncover a higher proportion of usability problems, compared with 'novice' evaluators. Therefore, a recommendation arising from the current study is that:

- **Recommendation 10:** further heuristic evaluation of Scottish HEI IR user interfaces should be performed by evaluators with extensive experience and expertise.

As noted in Section 3**,** Heuristic evaluation cannot capture the variety of real users' behavior (Preece, 1993; Brinck, 2001). For this reason, heuristic evaluation is often followed by user testing (Nielsen, 1994a; Macgregor, 2011). As the possibility of user testing was precluded by the time and resource limitations of the present study, a further recommendation is that:

- **Recommendation 11:** the validity of the results should be established by user testing of repository interfaces. This user testing should be carried out within local institutions, thereby enabling the results to directly inform local improvements.

As described in Section 3, the novel domain-specific heuristics proposed were developed in line with steps 1 to 6 of the 8-step formal methodology proposed by Quiñones, Rusu and Rusu (2018). As in the case of user testing, limitations of time and resources precluded completion of steps 7 and 8, which would involve expert evaluation to test the validity of the proposed heuristics, followed by refinement of the heuristics based on the expert feedback. Therefore, to address this limitation of the present study:

- **Recommendation 12:** future research is recommended to employ expert evaluation of the novel domain-specific heuristics, to test their validity and allow for further refinement.

As noted in Section 1, many academics will engage with the inward-facing deposit UI, as well as the outward-facing UI encountered by information seekers. As many of the existing studies on this topic are over 10 years old (Allen J., 2005; Cunningham, S.J. *et al.,* 2007; Davis and Connolly, 2007; Fried Foster and Gibbons, 2005), there is a need for further, updated research to assesses the usability of inward-facing administrative and deposit repository UIs, to complement the work undertaken in the present study. It is recommended that:

- **Recommendation 13:** future research is recommended to evaluate the usability of inward-facing UIs, to provide a fuller understanding of the usability issues affecting user acceptance of IRs.

Section 7.0 – Conclusions

7.1 Reflection on research questions and methods

The literature review revealed that many of the key studies on the topic of usability of institutional repositories are over 10 years old. This indicated a need for research in this area to be updated in order to assess the current repository landscape. Similarly, it is now over 20 years since Nielsen developed his set of 10 usability heuristics. Recent research (Rusu *et al*., 2010) has shown that evaluation based on Nielsen's heuristics can fail to capture domain-specific problems. Therefore, there was a need to develop a novel set of domain-specific heuristics appropriate to the evaluation of institutional repositories. Research Question 1 directly addressed this problem and a new set of domain-specific heuristics was proposed. It is hoped that this will be a useful tool for future evaluations.

Furthermore, most of the usability studies identified in the literature review employed heuristic evaluation or user testing methods across only 1 or 2 repository interfaces. While these focused studies provide detailed insight into the platforms discussed, the limited scope precludes the emergence of any wider overview of repository usability. Research Question 2 successfully addressed this gap, by providing a broader picture of the current state of play of repository usability within the Scottish HEI sector, in which the technology is relatively well established. In this respect, Research Question 2 facilitates an understanding of the extent to which usability issues have been resolved thus far and where there is still room for improvement. As the results showed, the high overall number of usability violations, including a significant number of major violations, encountered in the present study demonstrate that usability remains a key factor impacting on the user experience of institutional repositories provided by Scottish HEIs.

As noted in the Introduction and in Section 5, the usability of repositories can have a significant impact on levels of user acceptance. More recent commentary by Tay (2017) and Van de Velde (2016) highlight poor usability as a key reason for user non-acceptance of repositories. Therefore, there is a need to identify the specific areas in which usability could be improved, in order to address persistent issues surrounding user uptake and engagement. Research Question 3 successfully addressed this important issue, enabling the identification of priority areas of improvement across the 18 repository interfaces that were evaluated.

7.2 Reflection on research and learning outcomes

The intended research outcomes of providing a tool for the evaluation of institutional repositories, using this tool to evaluate the usability of Scottish HEI repositories and identify priority areas for improvement were achieved. It is hoped that the present study will draw renewed attention to the issue of repository usability and prompt further research in this area.

A key intended learning outcome of developing an understanding of the concept of usability in the field of human-computer interaction was also realised. Performing the literature review enabled the researcher to gain familiarity with key definitions and concepts, as well as develop knowledge of the varied methods used to assess usability. Moreover, valuable experience was gained in performing heuristic evaluation and in applying quantitative analysis to interpret the results and identify the priority areas for improvement. The researcher also developed an in-depth knowledge of the factors affecting repository usability and built-up substantial insight into the factors affecting the usability of repositories provided by Scottish HEIs.

7.3 Concluding comments

In conclusion, this dissertation developed and applied a novel set of domain-specific heuristics to the evaluation of the 18 institutional repositories provided by Scottish HEIs. A significant number of usability issues were uncovered, demonstrating the need for a renewed focus on this issue. Recommendations were provided, based on the identification of the priority areas of concern. Furthermore, suggestions for future research were provided, aimed at addressing the limitations of the present study and augmenting our understanding of usability issues in relation to the current institutional repository landscape.

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Glossary

ARMA – Association of Research Managers and Administrators

HEI – higher education institution

IR – institutional repository

Jisc – Joint Information Systems Committtee

REF – Research Excellence Framework

RLUK – Research Libraries UK

SCONUL – Society of College, National and University Libraries

UI – user interface

UKCoRR – United Kingdom Council of Research Repositories

Appendices

Appendix 1 – Scottish HEI Information

No.	HE provider	Institution Size	Type of University	Software
1	The University of Edinburgh	Large	Ancient universities	DSpace
2	The University of Glasgow	Large	Ancient universities	Eprints
3	The University of Strathclyde	Large	Chartered universities	EPrints
4	Glasgow Caledonian University	Mid-size	Post - 1992	PURE
5	The University of the West of Scotland	Mid-size	Post - 1992	PURE
6	The Open University	Mid-size	The Open University	EPrints
7	The University of Dundee	Mid-size	Chartered universities	PURE
8	The University of Aberdeen	Mid-size	Ancient universities	DSpace
9	Edinburgh Napier University	Mid-size	Post - 1992	WorkTribe
10	The University of Stirling	Mid-size	Chartered universities	DSpace
11	The Robert Gordon University	Mid-size	Post - 1992	DSpace
12	Heriot-Watt University	Mid-size	Chartered universities	PURE
13	The University of St Andrews	Mid-size	Ancient universities	DSpace
14	University of the Highlands and Islands	Small	Partnership of colleges	PURE
15	Queen Margaret University, Edinburgh	Small	Post - 1992	DSpace
16	University of Abertay Dundee	Small	Post - 1992	PURE
17	Glasgow School of Art	Small	Specialist institutions	EPrints
18	SRUC	Small	Specialist institutions	DSpace

Key: (Institution Size)		
Large:	> 20,000 students	>1500 members of staff
Mid-size:	12,000-20,000 students	300-1500 members of staff
Small:	<12,000 students	< 300 members of staff

Notes:

*****All information regarding institution size was obtained from the Higher Education Statistics Agency (2018).

** The Royal Conservatoire of Scotland (RCS) is not included in the above table. The RCS is a small, specialist performing arts institution. The University of St. Andrew's provides repository services on behalf of the RCS.

Appendix 2 – List of Articles Selected for Coding

1. Aljohani, M., Blustein, J. (2015) 'Personas Help Understand Users' Needs, Goals and Desires in an Online Institutional Repository' *International Scholarly and Scientific Research & Innovation*, 92(2), pp.629-636.

2. Davis, P.M. and M.L.J. Conolly (2007) 'Institutional Repositories: Evaluating the Reasons for Non-Use of Cornell's Installation of Dspace'. *D-Lib* 13(3), pp.1-19.

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8. Maness, J.M., Miaskiewicz, T., Sumner, T. (2008) 'Using Personas to Understand the Needs and Goals of Institutional Repository Users'. *D-Lib Magazine,* 14(9/10) [unpaged].

9. St. Jean, B et al. (2011) 'Unheard Voices: Institutional Repository End-Users', *College & Research Libraries* 72(1), pp.21-42.

10. Waugh, L., Hamner, J., Klein, J., Brannon, S. (2015) 'Evaluating the University of North Texas' Digital Collections and Institutional Repository: An Exploratory Assessment of Stakeholder Perceptions and Use' *The Journal of Academic Librarianship,* 41, pp.744-750.

11. Zhang, T., Maron, D., Charles, C. (2013) 'Usability evaluation of a research repository and collaboration website'. *Journal of Web Librarianship*, 7(1), pp.58-82.

Appendix 3 – Example of Table Used to Record Heuristic Violations

Institution: 3 **Heuristics**	**Issue Description (brief)**	**Severity**
H1		-
H2	A good range of browsing options are provided, including by author and college or school. However, it would also be useful for the user to be able to browse by content type as one of the main browse menu options (you can filter by item type once you have first chosen to browse by another category, such as author).	1
H3		-
H4		-
H5	Some technical terms are used in the 'About Strathprints' section that could perhaps be better explained.	2
H6	A good range of help and supporting guidance is provided re using the depository, including supporting guidance for information seekers in the form of guidance on using the advanced search feature. The pages offering broader advice on open access issues more generally are still under development but contact details for the OA team are provided in the interim.	1
H7		-
H8		-
H9		-
H10		-
H11	Users were not provided with confirmation messages before committing to key actions.	1
H12		-
H13	Better automation of actions could be provided, such as the ability to save previous searches or include 'favourite searches'. Users are not able to tailor the interface for personal preference or to perform frequent actions more easily.	2
H14		-

Appendix 4 – Full Set of Results (Heuristic Violations)

Institution No.	Software	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	H13	H14	Cosmetic	Minor	Major	Total
1	PURE	0	2	2	3	2	2	2	0	0	0	1	2	2	0	1	7	1	9
2	EPrints	1	1	1	2	0	2	2	0	0	0	1	2	2	0	4	5	0	9
3	EPrints	0	1	0	0	2	1	0	0	0	0	1	0	2	0	3	2	0	5
4	PURE	2	2	2	2	1	3	2	0	1	2	1	2	2	0	3	8	1	12
5	PURE	0	2	2	3	2	3	2	0	0	0	1	2	2	1	2	6	2	10
6	EPrints	0	1	2	0	0	0	2	0	0	2	1	0	2	0	2	4	0	6
7	PURE	0	2	2	3	2	3	2	0	0	0	2	2	2	2	0	8	2	10
8	DSpace	0	2	1	3	2	3	3	0	0	0	1	2	2	0	2	4	3	9
9	WorkTribe	3	3	2	1	1	2	2	0	2	0	2	2	2	2	2	8	2	12
10	DSpace	0	2	2	2	1	2	3	0	0	2	1	0	2	0	2	6	1	9
11	DSpace	0	2	1	3	0	1	3	0	3	0	1	0	2	0	3	2	3	8
12	PURE	0	2	2	3	2	3	0	0	0	0	1	2	2	0	1	5	2	8
13	DSpace	0	1	1	3	0	1	0	0	0	0	1	1	2	0	5	1	1	7
14	PURE	2	0	0	3	1	2	2	0	1	0	2	1	2	1	4	5	1	10
15	DSpace	0	2	0	1	0	3	3	0	0	0	1	2	2	0	2	3	2	7
16	PURE	0	2	2	2	0	3	2	0	0	0	1	2	2	0	1	6	1	8
17	EPrints	0	0	0	0	0	0	0	0	0	1	0	1	2	2	2	1	0	3
18	DSpace	0	2	1	3	0	2	3	0	0	0	1	0	2	0	2	3	2	7
Cosmetic		1	4	5	2	4	3	0	0	2	1	14	3	0	2	**41**			
Minor		2	11	9	4	6	6	9	0	1	3	3	10	18	3		**85**		
Major		1	1	0	9	0	7	5	0	1	0	0	0	0	0			**24**	

Total number of all (cosmetic, minor and major) heuristic violations across all 18 institutions: 150

Appendix 5 – Total Heuristic Violations by Software

	Worktribe				Dspace				PURE				Eprints				All			All Total
	Cosmetic	Minor	Major	All	Cosmetic	Minor	Major	All	Cosmetic	Minor	Major	All	Cosmetic	Minor	Major	All	Cosmetic	Minor	Major	
H1	0	0	1	1	0	0	0	0	0	2	0	2	1	0	0	1	1	2	1	4
H2	0	0	1	1	1	5	0	6	0	6	0	6	3	0	0	3	4	11	1	16
H3	0	1	0	1	4	1	0	5	0	6	0	6	1	1	0	2	5	9	0	14
H4	1	0	0	1	1	1	4	6	0	2	5	7	0	1	0	1	2	4	4	10
H5	1	0	0	1	1	1	0	2	2	4	0	6	0	1	0	1	4	6	0	10
H6	0	1	0	1	2	2	2	6	0	2	5	7	1	1	0	2	3	6	2	11
H7	0	1	0	1	0	0	5	5	0	6	0	6	0	2	0	2	0	9	5	14
H8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H9	0	1	0	1	0	0	1	1	2	0	0	2	0	0	0	0	2	1	1	4
H10	0	0	0	0	0	1	0	1	0	1	0	1	1	1	0	2	1	3	0	4
H11	0	1	0	1	6	0	0	6	5	2	0	7	3	0	0	3	14	3	0	17
H12	0	1	0	1	1	2	0	3	1	6	0	7	1	1	0	2	3	10	0	13
H13	0	1	0	1	0	6	0	6	0	7	0	7	0	4	0	4	0	18	0	18
H14	0	1	0	1	0	0	0	0	2	1	0	3	0	1	0	1	2	3	0	5
All	2	8	2	12	16	19	12	47	12	45	10	67	11	13	0	24	41	85	24	150