Chapter 12
A Framework for the Analysis of Personal Learning Networks

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12.1 Background

Although a long-established physical phenomenon, it is particularly since the evolution of the World Wide Web in the early 1990s that networks have become increasingly central to how we understand the world and undertake daily life. In academia, networks have appeared as an analytical, conceptual or explanatory approach since the 1920s (e.g. Bott & Moreno are cited in Scott, 2017). However, it is over the past 30 years that networks have grown in importance and application across diverse academic fields, including social sciences (e.g. Castells, 2011, vol. 12; Law, 1992, 2008; Rainie & Wellman, 2012), mathematics (e.g. Scott, 1988), and education (e.g. Siemens, 2005a, b; Downes, 2005, 2006; Goodyear, 2002, 2005). Networks today are also a central feature of daily life, not just of academia. The availability and affordability of mobile digital technologies, social media networks and wifi networks (for many but not all), mean that by the age of thirteen, 79% of UK children have a smartphone, 74% have an active social media profile, and they spend 15 h per week online (Ofcom Media Report: Children & Parents, 2016). Both active and passive social media use has led to social media networks becoming an influential part of how many individuals form their identity and their relationships to others (e.g. BBC School Report, 2016; Davies, 2015), earn an income (e.g. emarketer, 2016), or feel excluded or isolated (e.g. O'Keeffe & Clarke-Pearson, 2011; Luxton et al., 2012). However, social media networks are just the most visible of a myriad of networks in which we exist, both online, such as forums, class groups, Teams chats. . .etc., and offline, such as family and friendship groups, clubs,

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neighbourhoods…etc. In short, networks have become the defining framework for modern life, inextricably part of the activities of living, learning and working to such an extent that it becomes increasingly unproductive to consider an individual separately from the networks to which they belong.

Sociotechnical Theory (e.g. Cummings, 1978; Bijker, 1997; Geels, 2002) formalises this interdependence by suggesting that the development of societies and technologies are reciprocally co-dependent and that both social and technical phenomena cannot be fully understood in isolation from the other. Applied to education, this means that learning, as a process, cannot be separated from the networks used for learning. In practical terms, a typical HE undergraduate arrives at their institution with a well-established network of digital (online) and non-digital (offline) relationships to people, devices, services and information resources that they have seamlessly integrated into their regular activities in all contexts. In short, they are at the centre of their own Personal Learning Network (PLN).

Within education, the networked learning community is the only branch to have fully recognised this sociotechnical relationship and the increasing centrality of networks to daily life and study. Many researchers (e.g. Siemens, 2005b; Downes, 2007; Kop & Hill, 2008; Carvalho & Goodyear, 2014; Moses & Duin, 2015; Van Waes et al., 2016; Jordan, 2016; Krutka & Carpenter, 2016; Trust et al., 2017; Visser et al., 2014) have explored networks over the past 15 or more years; however, there remains a lack of empirical data in relation to PLNs in particular. It is therefore timely and important that research which aims to map and analyse the size, use and interaction preferences of the PLNs of diverse individuals is undertaken, in order to identify any meaningful patterns within and between these networks. In light of the rapid and fundamental changes to the HE landscape resulting from the response to the Covid-19 pandemic, the insights and evidence from this PLN research can be used to help underpin the necessary conversations concerning the most appropriate HE pedagogies for this new landscape, as well as being meaningfully applied to HE networked learning design. The application of effective digital pedagogies and learning design at this time may, in turn, help avoid the potential risk of a disconnect between students' educational expectations for online learning and the online and blended learning experiences they actually receive from their HE institution. Such a disconnect, if not avoided, may have negative consequences for learning gain, student engagement and satisfaction, and the British Teaching Excellence Framework ratings, which directly impact HE funding.

12.2 What Is a Personal Learning Network (PLN)?

Personal Learning Networks (PLNs) are complex to define and there is no consensus on a single definition within the literature. It is perhaps therefore worth beginning with what PLNs are not. PLNs are not the same as a Personal Learning Environment (PLE), which is an institutionally supported system for student interactions with learning technology (White & Davis, 2013), or an institutional Virtual Learning

Environment (VLE). Rather, PLNs are autonomously created by an individual and feature the people, devices, services and resources for which they have a personal preference or need for at a given point in time.

Also, although there are a number of similarities between them, PLNs are also not Professional Learning Networks (Trust, 2012), Personal Professional Learning Networks (Rajagopal et al., 2012), or Personal Knowledge Networks (Grabher & Ibert, 2005). This is because PLNs are not 'professional' (i.e. based in a workplace), and 'knowledge' implies something different from learning (an outcome rather than a process). Also, a PLN is not a 'learning network', which in the literature is synonymous with a community of individuals intentionally interacting for a shared learning goal, interest or need (a community-network view), rather they are centred on an individual.

Now we know what a PLN is not, what actually is it? In line with others (e.g. Siemens, 2005b; Downes, 2007; Kop & Hill, 2008; Carvalho & Goodyear, 2014), this research conceptualises a Personal Learning Network in its broadest form—that any type of interaction undertaken by any individual, for any purpose (formal, non-formal and informal learning and/or personal pleasure), can present an opportunity for learning. Hence, all daily interactions with technologies, people, information and services autonomously undertaken by a single individual embedded in their wider personal contexts form the network. Hence, a PLN is simultaneously a learning artefact (and therefore capable of becoming a unit of analysis) and a real-world tool which "*foster[s] interaction amongst and a learning process 'within' its participants*" (Rusman et al., 2016).

Consequently, drawing together the key elements of the various definitions in the literature, and taking as broad a view of learning as possible, this paper defines a PLN as:

> *the total preferred connections to and interactions with the different people, technological devices, services, and information resources that an individual chooses to use to assist with any learning activity in all learning contexts for the purposes of achieving any form of learning outcome.*

PLNs are (largely) autonomously built, maintained and used by the creator, but are also heavily shaped by the wider sociocultural contexts within which the creator and the network are situated. PLN interactions can occur online and off, and in formal, non-formal and informal learning contexts. They are dynamic and subject to constant change and evolution as a result of individual drivers and contexts, wider contextual influences, and the technological affordances of the time.

12.3 A Framework for the Analysis of Personal Learning Networks: The Design

This section presents the theories, principles, existing research and design rationale which underpin the Framework. Firstly, the Framework for the Analysis of PLNs aims to enable the answer to three basic questions:

1. What can be learnt about three aspects (size, use and interaction preferences) of the PLNs of diverse individuals and groups?
2. What are the impacts of the wider shaping effects of gender, life stage, ethnicity, region of residence, main activity and attitude to technology on these three aspects of PLNs?
3. How can these findings inform HE networked learning pedagogy and design?

Traditionally in learning network research, it has been difficult to meaningfully compare individual network maps at the microlevel due to large network variations, where the networks will contain nodes that are unique to the individual and their context (e.g. Participant 1 interacts with Person Name A, while Participant 2 interacts with Person Name B—we will return to this theme later). This limits within-project comparisons of the networks of individual participants, and between-project comparisons of networks generated by different research projects. Furthermore, research which maps individual networks also tend to be constrained by small sample sizes, making meaningful generalisations from individual networks to larger groups problematic (e.g. Moses & Duin, 2015; Van Waes et al., 2016; Jordan, 2016).

Similarly, when studying whole networks at the macrolevel (consisting of the relationships between multiple individuals in a community), traditionally it has also been difficult to account for the shaping effects of the 'personal' factors which lead to individual differences in network behaviours, attitudes and connections (e.g. Krutka & Carpenter, 2016; Trust et al., 2017; Visser et al., 2014). This Framework has been designed to address the research questions by overcoming these traditional challenges in learning network research by adopting design principles which can bridge the gap between the micro- and the macro-scales of research.

The Framework for the analysis of PLNs is underpinned by connecting theories and concepts from a range of fields, including Education, Web Science, Digital Sociology and Network Science, as indicated in the graphic (Fig. 12.1).

From the Social Sciences, research by digital sociologists has identified a considerable range of shaping factors which can result in digital inequalities in access to technology; differences in digital literacies; and differing motivations to use technology. The literature (e.g. Pew Research Center, 2018; Ofcom, 2017; Orton-Johnson & Prior, 2013; Davies et al., 2012; Daniels et al., 2016; Witte & Mannon, 2010; Robinson et al., 2015) predicts that observable differences in PLNs based on Life Stage (age), Gender, Ethnicity, Country of Residence, and attitude to technology (position on the Digital Resident-Digital Visitor spectrum (White & Le Cornu, 2011)) should be evident. Learning from a trial version of the Framework further indicated that the Main Activity on the day of reporting (e.g. studying, working, caring, volunteering, leisure) is likely to have an impact on a PLN as well. Hence, these six external shaping factors form the 'Personal' aspects of the PLN Framework.

From Education, social constructivism focusses on the key role played by interaction in learning, suggesting that these interactions should be meaningful if they are to be effective for learning purposes (e.g. Vygotsky's Zone of Proximal Development (Vygotsky, 1978)). In addition, also stemming from Vygotsky's work,

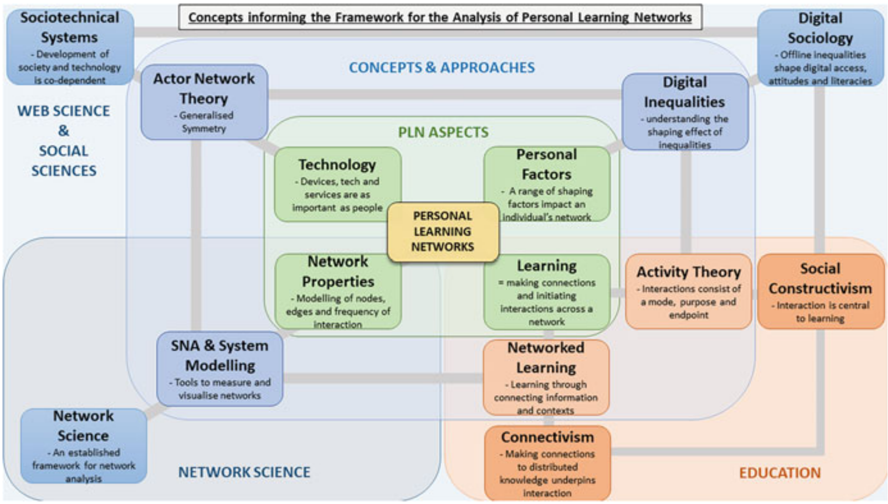

Fig. 12.1 The interdisciplinary concepts informing the design of the framework for the analysis of PLNs

Activity Theory introduces the importance of the mediating artefact, or device, when undertaking interactions (e.g. Engeström, 2001; Carvalho & Goodyear, 2014). Next, drawing from a second learning theory—Connectivism (e.g. Siemens, 2005a, b; Downes, 2005, 2006)—and from the field of Networked Learning (e.g. Illich, 1971; Goodyear, 2002, 2005; De Laat et al., 2006), it is also the case that before meaningful interaction can occur, connections to distributed knowledge and diverse people must be made and patterns of relationships across learning contexts and knowledge domains identified. The conceptualisation of learning as involving interactions for a meaningful purpose undertaken through a mediating device (including face-to-face) across a network of connections to people and information informs the 'Learning' aspect of PLN research.

Next, Web Science suggests that it is impossible to understand a phenomenon without understanding that it has both a social (human) and a technical (non-human) aspect, and that these cannot and should not be understood separately. This is known as Sociotechnical Theory (e.g. Cummings, 1978; Trist, 1981; Bijker, 1997; Geels, 2002), and is formalised for analysis by the concept of Generalised Symmetry from Actor Network Theory (e.g. Latour, 1987; Law, 1992; Callon, 1999), in which human and non-human actors in a network must be considered as equally significant to the construction and use of the network. This informs the conceptualisation of an interaction as being equally meaningful whether it be with a human other or with a non-human endpoint.

In addition, Network Science (and Mathematics) also provides a toolkit for the empirical analysis and mapping of networks—Social Network Analysis (e.g. Granovetter, 1977; Scott, 1988; Borgatti et al., 2018), where the frequency of network interactions can be measured and networks visualised. To this System Modelling (e.g. Checkland, 1981, 2000; Checkland & Scholes, 1990; Davies & Ledington, 1991; Wand, 1996) introduces the idea of abstraction and generalisation for modelling networks across different domains. Together, these concepts and approaches inform the 'Network' aspects of PLN research.

Taken together, the understanding of PLNs provided by this range of theories allows for a full conceptualisation of PLNs as an ego-centric interaction network consisting of an Interaction Mode (the medium through which an interaction is conducted), an Interaction Purpose (an intentional activity) and an Interaction Endpoint (a human or non-human other). The Framework views learning as simultaneously individual (i.e. autonomous and uniquely shaped by contextual factors—'Personal'), social (i.e. involving meaningful interactions with human and non-human others—'Learning') and networked (i.e. involving the making and maintaining of diverse connections—'Networks'). In other words, a Personal Learning Network features meaningful interactions across consistent network paths involving a Mode, a Purpose and an Endpoint.

Consequently, a Framework for the Analysis of PLNs has been developed which structures formal network analysis around a conceptualisation for the mapping of *individual* PLNs based on an interaction path from the Ego to a Mode, which is used for a Purpose, to interact with an Endpoint (see Fig. 12.2).

However, the Framework needs to go further if it is to successfully account for the impact of the external shaping factors on PLN size and use (and bridge the gap between micro- and macrolevel network research), by enabling the aggregation of individual PLN maps for direct analysis and comparison. Hence the Framework proposes two further approaches adapted from System Modelling. The first is that the researcher, based on a rigorous review of the literature, must define the node sets (Mode, Purpose, Endpoint) that feature in the network in advance of going into the field—a form of Abstraction. This is the process which has been detailed in this section so far and summarised in Fig. 12.2.

The second System Modelling approach is the identification and definition of generalised nodes within those Node Sets—referred to as Generalisation. For example, it is not particularly informative to know that John interacts with Jane or with Facebook if the aim is to try to compare John's network with a Random Other, who is unlikely to know Jane and who might not use Facebook. Therefore, within the node sets identified and abstracted from the literature (Mode, Purpose, Endpoint), generalised nodes such as Smartphone (as opposed to 'iPhone10') and Face-to-Face (to encompass all non-digital interactions, including with non-humans, e.g. reading a newspaper) form part of the Interaction Mode node set; Gathering Information and Collaborating and Communicating (instead of 'reading about crystalography' or 'groupwork on my module assessment') form part of the Interaction Purpose node set; and Social Network Services or Friends (rather than 'Facebook' or 'Jane') can be found in the Interaction Endpoints node set, for example.

The advantage of a Generalisation approach is that by defining the generalised nodes in the network in advance, every individual PLN will consist of the same nodes (if present), meaning that there will be no variation between individual

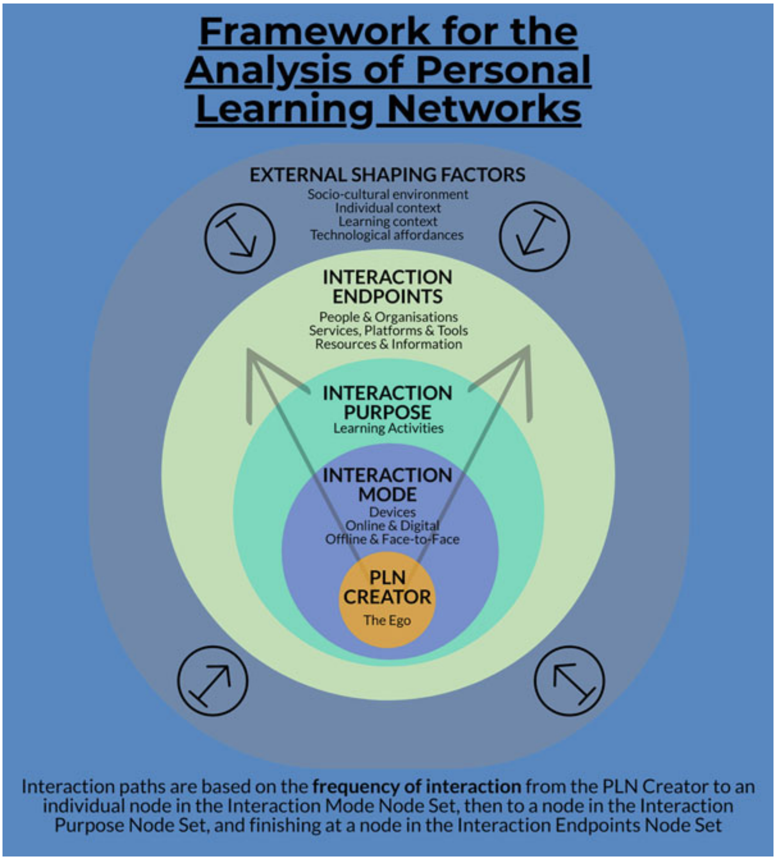

Fig. 12.2 The Framework for the Analysis of Personal Learning Networks

respondents at the network scale. This means that individual PLNs can be directly compared and aggregated. Importantly, it also means that individual PLNs can be aggregated into subsets, according to a range of shaping factors (e.g. life stage, gender, ethnicity…etc.), thereby allowing the significance of the effect of these factors on the size and use of PLNs to be statistically analysed.

However, this solution does require considerable research to enable evidence-based choices over what to include/exclude from the network, what abstractions to make and how to generalise nodes in a reasonable way. In addition, this pre-determining of generalised nodes (and node sets) does mean that some granularity is lost; however, that is a necessary consequence of reconciling the micro and macro.

In summary, based on existing theories and research, the Framework for the Analysis of PLNs conceptualises PLNs as an egocentric interaction network, featuring pre-determined, generalised nodes, grouped into pre-determined abstracted node sets (Interaction Mode, Purpose and Endpoint). This ensures continuity between the networks of individual respondents, meaning that PLNs at the individual level can be meaningfully and robustly analysed based on the number of nodes and the number of interactions in the network. For group and whole sample levels, at large sample sizes, mean number of nodes and mean number of interactions can be used for statistical analysis. In this way, it is envisioned that the Framework will contribute to bridging the gap between the micro- and the macrolevels of network analysis, and potentially open new possibilities for Networked Learning research.

12.4 Methodology

The Framework was used to inform the design of an online, closed question, quantitative survey, hosted on iSurvey as the sole form of data collection. The survey asked respondents to recall the number of times (frequency) they interacted along single paths through their learning network during a single day. These paths emanate from the PLN creator via an Interaction Mode (mobile/smartphone; tablet; laptop; desktop; and face-to-face/non-digital), through an Interaction Purpose (searching and browsing; gathering information; communicating and collaborating; creating and sharing; socialising; and gaming/hobbies/sport), to an Interaction Endpoint (too many to list, but which includes a range of humans and non-humans). It is important to note that Post-event Recall was, therefore, a potential limiting factor to this methodology, as was sample bias resulting from the use of an online survey.

In a novel approach to sampling and data collection, this survey was hosted on the 'Learning in the Network Age' MOOC (University of Southampton/FutureLearn https://www.futurelearn.com/courses/learning-network-age, which is open for learner enrolment on a continuous basis). The MOOC was written and produced by this author, in collaboration with others, specifically for this research. This provided a large, self-selecting, non-probability sample from a finite universe of MOOC learners. Furthermore, a unique, bespoke, automated analysis and mapping tool was commissioned to immediately turn the survey results into an individual online PLN map as well as generate the aggregated PLN maps for the whole sample and sample subsets (see Fig. 12.3). Participants could view their own PLN map and view and explore the aggregate maps online immediately on completion of the survey.

The use of the MOOC for data collection successfully returned a sample of 842 individuals from 92 different countries and 20 different ethnicities, but it also meant that further sample bias was inevitable. Clearly those who do not/cannot access the web (still about half the world's population), and those who can access the web but do not have the motivation or digital literacies to undertake self-directed online learning, or who do so using other MOOCs and platforms, or who have no interest in an 'education' MOOC are excluded from this sample.

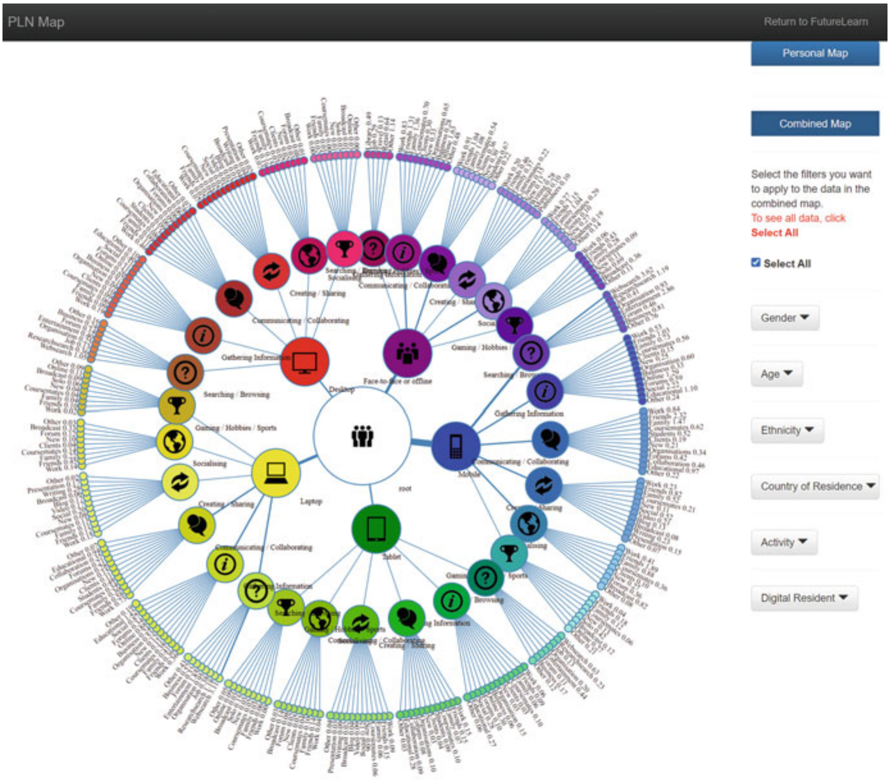

Fig. 12.3 The aggregated PLN map for the whole sample ($n = 842$). Please explore this network map for yourself on: https://mooc.it-innovation.soton.ac.uk/: password: 3563636 > Combined Map > Select All (note: this map remains a live tool and will change with every survey completion)

12.5 Data Analysis

The purposes of the data analysis are to robustly answer the first two research questions (see above) in particular. Data analysis consists of two main methods—the online PLN network maps produced by the bespoke mapping tool from the survey responses (see Fig. 12.3), and the raw .csv survey responses themselves. The raw data was cleaned (of incomplete and missing responses), grouped and coded (for ease of analysis) and where necessary transformed and aggregated (in SPSS), to provide datasets suitable for descriptive analysis and statistical significance testing.

Concerning the three PLN aspects (size, use and interaction preference), aggregated PLNs for sample subsets were visualised using the network map outputs of the bespoke online mapping tool (see Fig. 12.3). Network Size can be seen by the number of nodes in the network map. Network Use is visible as a percentage of total interactions (percentages are displayed as tool tips on-screen with mouse-over hover). Network Preferences are observable as thicker/thinner edges (connections) between network nodes representing a higher/lower amount of activity along that path. Preference is also visualised in the descriptive analysis of the cleaned raw data as a mean number of interactions (see the bar carts below). Concerning the impact of the six shaping factors on each aspect of a PLN (Mode, Purpose, Endpoint), the data was divided into the relevant subsets and corrected for variance (5% trimmed means) and skew (bootstrapped). Network Size was measured by testing the significance of any differences in the mean number of nodes for a sample subset. Network Use was measured by testing the significance of any differences in the mean number of interactions.

Statistical significance testing was conducted in SPSS using a univariate (1-way) ANOVA test for network size and a multivariate, repeated measures Mixed ANOVA test (2-way) featuring within-subject variables (the mean number of interactions with Mode, Purpose and Endpoint) and between-subject variables (the six external shaping factors) to compare means between different sample subsets. The tests returned significance values (at a confidence level of 95%, $p < 0.05$) for the main effect of the within-subject variable under test, the main effect of the between-subject variable under test and the interaction effect of the within- and between-subject variables. Where Mauchly's test of sphericity was violated, either Greenhouse-Geisser or Huynh-Feldt corrected significance values were used (Field, 2009). This analysis allowed an assessment of the significance in observed differences in the mean number of nodes and interactions to provide a detailed and granular understanding of how a PLN is impacted by the wider context in which its creator resides.

12.6 Results

The network map you can see above (Fig. 12.3) provides a visualisation of the aggregated PLN for the entire sample.

It mirrors the Framework in that the PLN creator (the ego) sits at the centre and interactions proceed in paths from them to Interaction Mode (the first ring of nodes), then to Interaction Purpose (the second ring of nodes), before culminating in an Interaction Endpoint (the third ring of nodes), where the numbers indicate the percentage of total interactions made along that single interaction path. The thicker the edge connecting each node, the more frequently that interaction has occurred. This provides a clear visualisation of the data returned from MOOC participants through the online survey—for example, the edge connecting the group ego to smartphone (blue) is thicker than those to any other Mode nodes (first ring) meaning that phone interactions are the most frequent and therefore also the most preferred.

The MOOC-based data collection methodology resulted in a total sample size, after cleaning and removal of significant outliers, of 842 respondents from 92 different countries and 20 different ethnicities and from the full range of ages, positions on the Digital Resident—Digital Visitor spectrum (White & Le Cornu, 2011) and main

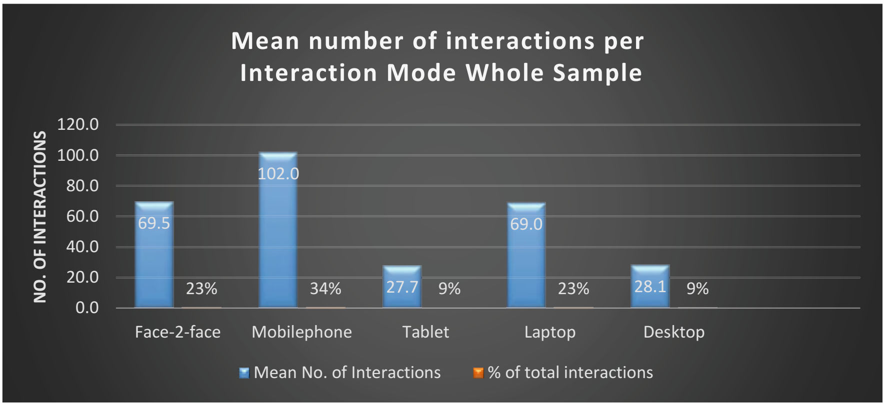

Fig. 12.4 Mean number of interactions and percentage of all PLN interactions by Interaction Mode

daily activities (Working, Studying, Caring and Volunteering or at Leisure/Free time), were returned. In total:

- 58% of respondents were female ($n = 491$);
- 37% were in Early Career (aged 26–45) ($n = 310$);
- 62% were of White ethnicity (White British, American, Irish, Any Other White) ($n = 530$);
- 61% were resident in Europe ($n = 509$);
- 43% classed themselves as a Digital Resident (position 0–3 on the Digital Resident-Digital Visitor spectrum) ($n = 365$);
- 71% were either working or studying as their main activity ($n = 595$).

Excluding significant outliers, results for the whole sample indicates that regardless of who we are, where we live, and our contexts, attitudes and activities (external shaping factors) our PLN will consist of an average of just under 62 nodes (mean network size (untrimmed) = 61.9) from a maximum possible network size of 335 nodes as defined in the Framework. We will use this network to make on average just over 296 interactions every day (see Fig. 12.4—network use). We have a strong preference for digital interaction modes making 77% of all daily interactions through a device and just 23% face-to-face (i.e. non-digital). We also prefer to interact 47% more often with smartphones than with any other mode (network preferences). Our PLNs, and our interactions, are clearly multimodal, but also demonstrate clear preference patterns.

Furthermore, we use our PLN to interact for a range of purposes, with the most preferred being gathering information (28% of all interactions and 22% more often than any other interaction purpose) (see Fig. 12.5).

In addition, we use our PLNs to interact almost equally as much with non-human endpoints (such as social media platforms, educational software (possible sample bias here), web search engines, and forums/chatrooms/blogs) as we do with human endpoints (such as friends, family and classmates) (see Figs. 12.6, 12.7 and 12.8).

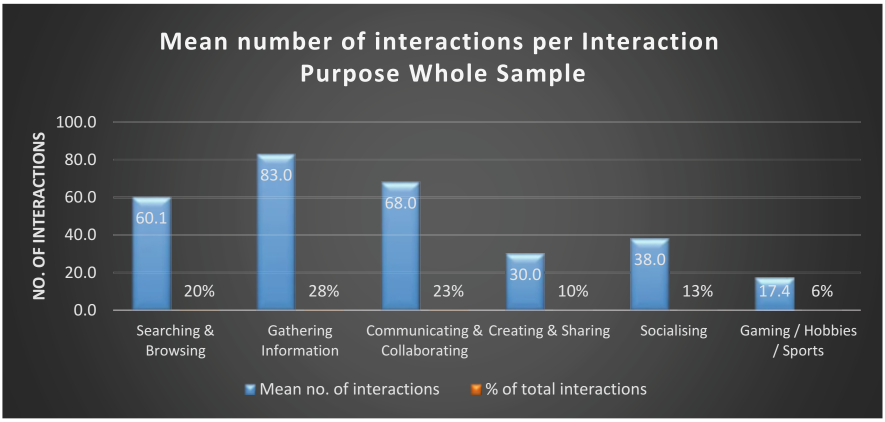

Fig. 12.5 Mean number of interactions and percentage of all PLN interactions by Interaction Purpose

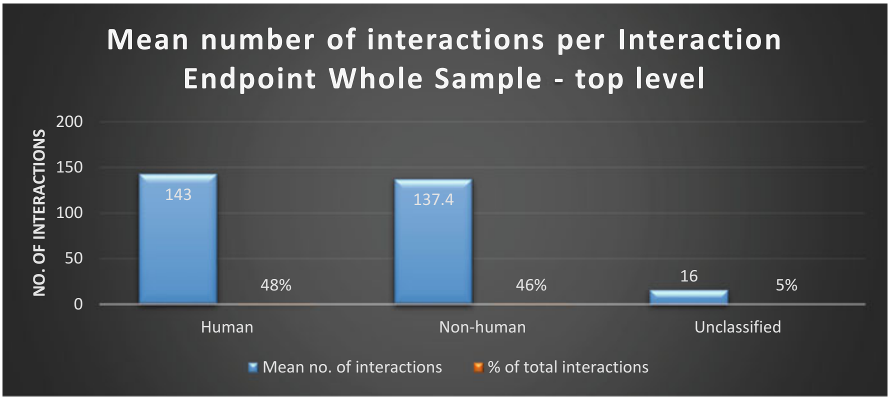

Fig. 12.6 Mean number of interactions and percentage of all PLN interactions with Humans and Non-humans

Across the entire sample there is a clear preference for smartphone interactions for the purposes of gathering information from friends or from social media platforms. This has interesting implications for networked learning design, which will be discussed later.

However, the Framework also allows the whole sample to be analysed according to the six external shaping factors and their associated subsets. These can be tested to see if one's gender, life stage and ethnicity, or where one lives, what one is doing and how one thinks about technology will significantly alter one's PLN. The data allows an analysis of Personal Learning Networks against three main network aspects: Network Size, Network Use and Network Preferences.

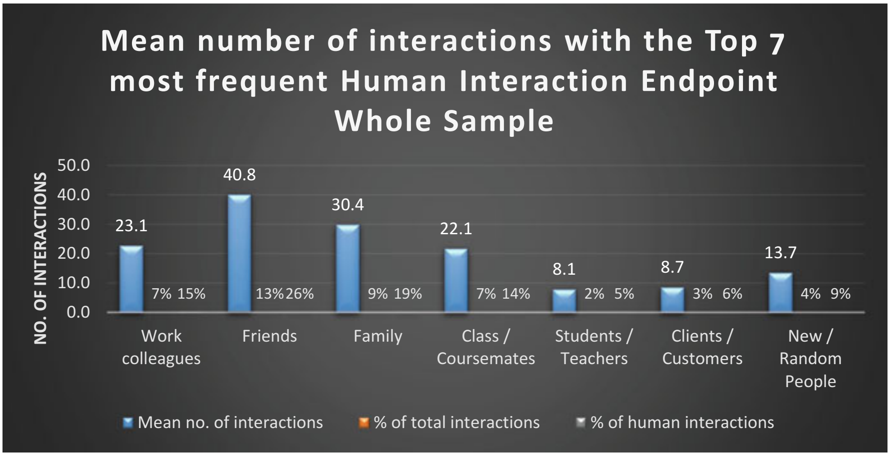

Fig. 12.7 Mean number of interactions and percentage of all PLN interactions with Human Interaction Endpoints

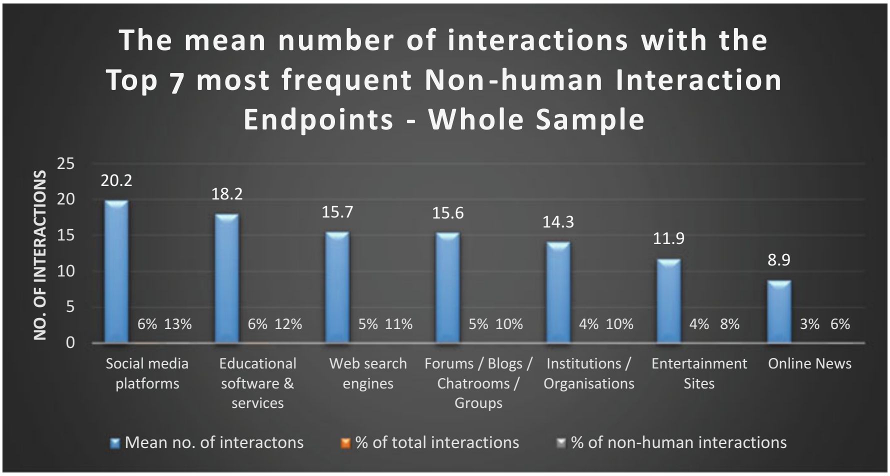

Fig. 12.8 Mean number of interactions and percentage of all PLN interactions with Non-human Interaction Endpoints

12.6.1 Network Size

First, Network Size is measured by the mean number of nodes for each subset. This data was analysed using 1-way ANOVA tests of significance on 5% trimmed means with bootstrapping to test the hypothesis that each external shaping does not impact the size of the network. The results indicate that:

- Gender *does not* significantly impact the size of the network (mean number of nodes: females = 59.2, males = 59.4—transgender and do-not-state were removed for analysis due to low sample size).
- Life Stage *does not* significantly impact the size of the network (mean number of nodes: Childhood (Under 18) = 43; University (18–25) = 59.7; Early Career (26–45) = 59.7; Late Career (46–65) = 60.6; Retirement (Over 65) = 62.8).
- Ethnic Group *does not* significantly impact the size of the network (mean number of nodes: White = 57.5; Black = 61.5; Asian = 62; Mixed Ethnicity = 64.6; All other ethnic groups (inc. Hispanic) = 67.5).
- Region of Residence *does* significantly impact the size of the network (mean number of nodes: Africa = 47.1; Europe = 57.8; North America = 58.3; Oceania = 58.9; Central, Southern and South-eastern Asia = 60.4; Western Asia = 64.1; Latin America and the Caribbean = 71.6; Eastern Asia (China, Japan, Hong Kong, South Korea and Taiwan) = 77.8).
- Main Activity (on the day of reporting) *does* significantly impact the size of the network (mean number of nodes: Leisure/Free time = 51.8; Caring (inc. childcare) and Volunteering = 56.2; Studying = 60.5; Working = 64.4)—simple tests of contrast indicate this significance is only between those at work and those at leisure.
- Attitude to Technology *does* significantly impact the size of the network (mean number of nodes: Digital Visitor = 49.6; Neutral = 56.7; Digital Resident = 67.2).

Hence, while gender, life stage and ethnicity do not affect the size of the PLN that an individual is able to create and use, where the individual lives, what their attitude to technology is, and whether they are at work or enjoying free time will impact the size of their network.

To summarise, the impact of the six external shaping factors that were analysed can be seen in Table 12.1.

Table 12.1 The impact of context on network size

External shaping factor	Impact on the size of a personal learning network (all aspects)
Gender	None
Life stage	None
Ethnic group	None
Region of residence	Very high
Main activity	High
Attitude to technology	Very high

12.6.2 Network Use

Secondly, Network Use is measured by the mean number of interactions (5% trimmed and bootstrapped) undertaken by a subset. This data was analysed using a Repeated Measures Mixed (2-way) ANOVA test of significance based on the combination of main effect of each external shaping factor (between-subject factor) on the mean number of interactions with a Mode, Purpose or Endpoint (within-subject factors) and whether there was an interaction effect between factors. The results indicate that:

- Gender *does not* significantly impact interactions with Interaction Mode (choice of device). However, Gender *does* significantly impact interactions for Interaction Purposes, and with Top-level Interaction Endpoints (see Fig. 12.9), Human Endpoints and Non-human Endpoints.

  Males are more active in the network generally making on average 22% more network interactions daily (female interactions = 270.9; male interactions = 328.2). Although gender does not impact the devices used for interactions, it does affect the purpose of those interactions, with males Gathering Information and Searching and Browsing significantly more frequently (+26% and +33% respectively). Gender also affects with whom/what interactions occur, with males making 19% more interactions with non-human endpoints than females overall, including, for example, 21% more social media platform interactions and 48% more interactions with forums/chatrooms/blogs. Males also make 34% more interactions with their class/coursemates than do females. Interestingly, the *only* category where females make more interactions than males is between student and teacher and/or teacher and student. Overall, gender has a high impact on PLN use.

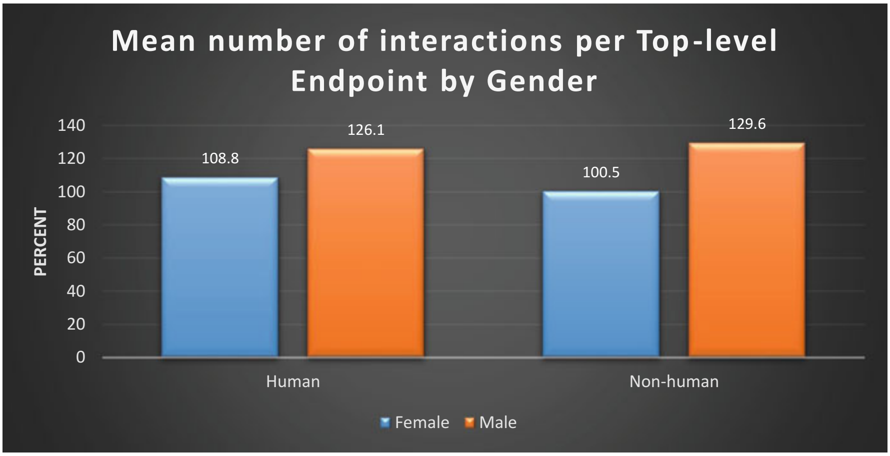

Fig. 12.9 Differences in mean number of interactions with humans and non-humans by gender

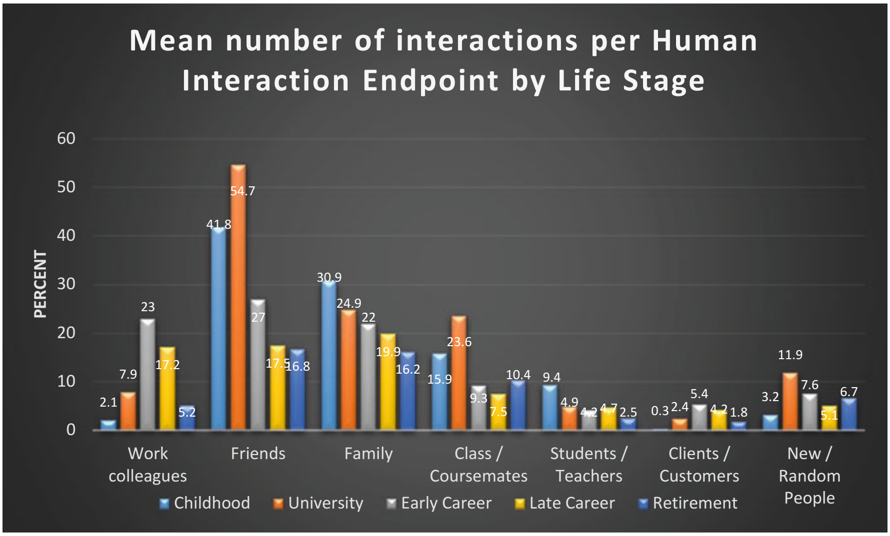

Fig. 12.10 Differences in mean number of interactions with humans by life stage

- Life Stage *does* significantly impact interactions with Interaction Mode (choice of device), for Interaction Purposes, and with Top-level Interaction Endpoints, Human Endpoints (see Fig. 12.10) and Non-human Endpoints. Simple tests of contrast indicated that there were significant differences between the University life stage and the Late Career and Retirement stages, but not between the University stage and Childhood and Early Career.

  Life Stage significantly impacts PLN use in all aspects, with the differences mostly observed between earlier life stages (Childhood, University and Early Career—Under 18–45) and later life stages (Late Career and Retirement—45+). After an initial increase in interactions from Childhood (mean interactions = 289.5) to University (mean interactions = 372.7), the number of interactions undertaken daily decreases steadily over working life and into Retirement (mean interactions = 203). Individuals in the University stage are the most active in their networks, undertaking 25% more daily interactions than the second most active group (Early Career). Those at the University stage also interact considerably more for Searching and Browsing and Socialising than any other life stage (+48% and +57% more than the next highest stages) and interact more frequently with Friends (+31%), Class/Coursemates (+48%) and New or Random People (+55%) than the next most active groups (see Fig. 12.10). Furthermore, those at the University stage interact with social media platforms 46% more often than any other life stage and make 55% more web searches. Overall, Life Stage has a very high impact on PLN use.
- Ethnic Group *does* significantly impact interactions with Interaction Mode (choice of device), for Interaction Purposes (see Fig. 12.11), and with Top-level Interaction Endpoints and Human Endpoints, but *does not* significantly impact

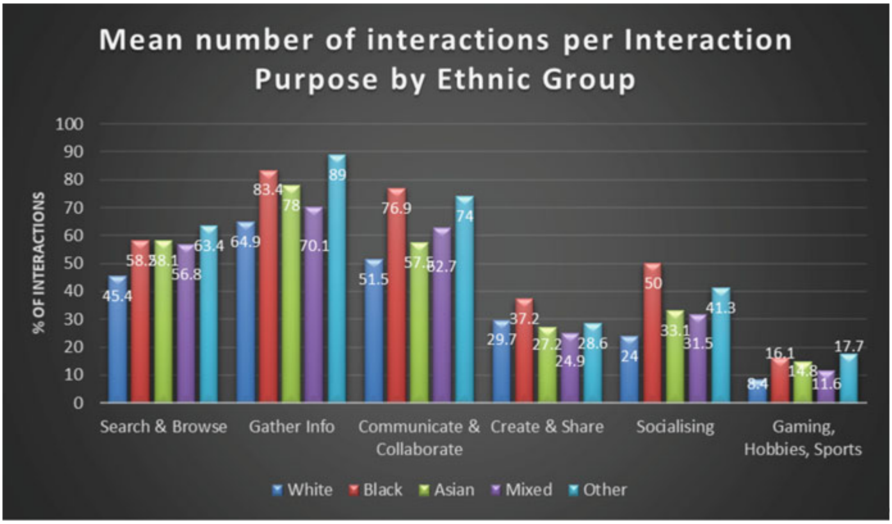

Fig. 12.11 Differences in mean number of interactions for different purposes by ethnic group

interactions with Non-human Endpoints. Simple tests of contrast indicated that there were *only* significant differences between the Other ethnic group (Hispanic, Any Other ethnicity) and the White ethnic group.

Ethnic Group has a limited significant effect on the number of interactions in a PLN, only if the PLN creator is of White ethnicity or Other ethnicity. Those of White ethnicity are the least active of the ethnic groups, making 27% fewer daily interactions than the most active group (Africans) and 10% fewer than the next least active group (Asians). Those of the Other ethnic group make 70% more smartphone and 55% more face-to-face interactions than do the White group. They also interact 44% more frequently for the purpose of Communicating and Collaborating and 110% more for Gaming/Hobbies/Sports than do the White group (see Fig. 12.11). Those of Other ethnicity make 65% more human interactions, including 80% more Family and 181% more Class/Coursemate interactions than their White counterparts. They also make 25% more social media platform interactions and perform 38% more web searches. However, these dramatic results may stem from the far larger sample size for the White group ($n = 529$) than the Other group ($n = 68$), which consequently includes many more individuals from the later Life Stages who make fewer daily interactions. Statistically, as Life Stage has a far larger impact on all aspects of a PLN than does Ethnic Group, the results presented in this section must not be overstated. Overall Ethnic Group has a low impact on PLN use.

- Region of Residence *does not* significantly impact interactions with Interaction Mode (choice of device), for Interaction Purposes, and with Top-level Interaction Endpoints, Human Endpoints nor Non-human Endpoints.

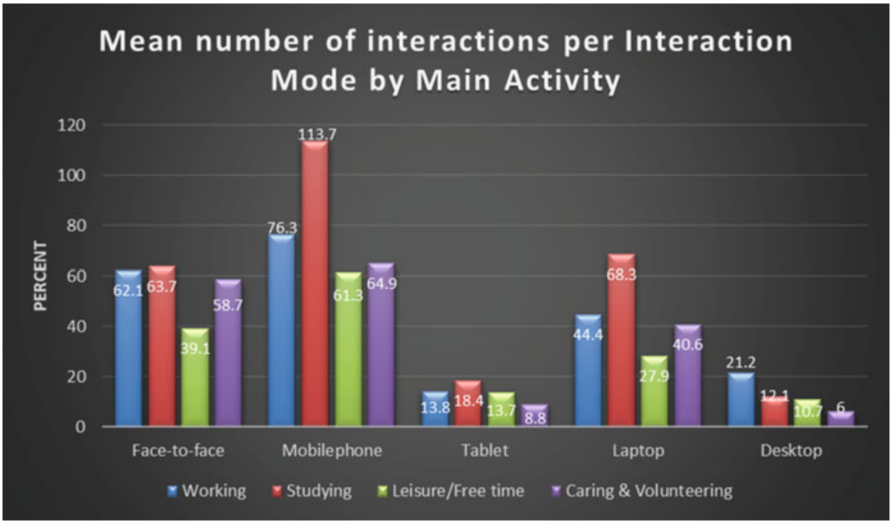

Fig. 12.12 Differences in mean number of interactions for different devices by main activity

Overall, Region of Residence has no impact on the use of a PLN.

- Main Activity on the day of reporting *does* significantly impact interactions with Interaction Mode (choice of device) (see Fig. 12.12), for Interaction Purposes, and with Top-level Interaction Endpoints, Human Endpoints and Non-human Endpoints. Simple tests of contrast indicated that there were significant differences between all main activity groups except the Working and Caring/Volunteering groups.

Those who were Studying were the most active in the network, making 30% more interactions than the next most active group (Working) and 52% more interactions than the least active group (Leisure/Free time). Individuals who were Studying made 49% more smartphone and 54% more laptop interactions than the next most active group (Working) (see Fig. 12.12). Interestingly, those who were Studying made the most number of interactions for the purpose of Socialising of any group, with 103% more daily interactions for this purpose than those who were enjoying leisure and free time. Equally, they interacted 88% more with Human endpoints (inc. 75% more Friend interactions) and 74% more often with Non-human endpoints (inc. 66% more interactions with social media platforms), than individuals at Leisure. Overall, Main Activity has a high impact on PLN use.

- Attitude to Technology *does* significantly impact interactions with Interaction Mode (choice of device), for Interaction Purposes, and with Top-level Interaction Endpoints, Human Endpoints and Non-human Endpoints. Simple tests of contrast indicated that there was a significant difference between Digital Residents and Digital Visitors, but not between Neutral and either Visitors or Residents.

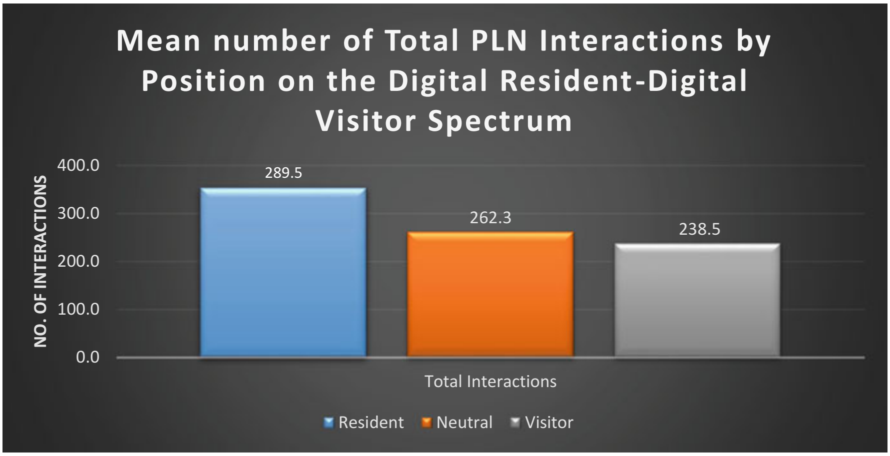

Fig. 12.13 Differences in mean number of total interactions by attitude to technology

Table 12.2 The impact on network use

External shaping factor	Impact on the use of a personal learning network (all aspects)
Gender	High
Life stage	Very high
Ethnic group	Low
Region of residence	None
Main activity	High
Attitude to technology	High

Those with the most positive attitude to technology (Digital Residents) were the most active in their networks, making 21% more interactions those with a more negative attitude to technology (Digital Visitors) (see Fig. 12.13). Notably, Residents made 85% more smartphone and 86% more laptop interactions than Visitors. They also interacted 96% more frequently for the purpose of Creating and Sharing and 119% more for Socialising, making 76% more Friend interactions and 194% more social media platform interactions than Digital Visitors. Overall, attitude to technology has a high impact on PLN use.

To summarise, the impact of the six external shaping factors that were analysed can be seen in Table 12.2.

12.6.3 Network Preferences

In contrast to the results for network size and network use, which show a moderate to high degree of variation between sample subsets across all aspects of the network (Mode, Purpose, Endpoints) resulting from the effect of each of the external shaping factors, Network Preferences are much more homogenous in most cases.

Firstly, the descriptive statistics (including the bar charts) allow the identification of interaction patterns within and between subsets. The analysis indicates that regardless of all Gender, Life Stage, Ethnic Group, Region of Residence, Main Activity and Attitude to Technology subsets, smartphone interactions are *always and by far* the most preferred Mode (the only exceptions being for people in Retirement or those living in Oceania who prefer face-to-face interactions the most). This striking pattern clearly indicates how embedded, central and important the smartphone is to daily interactions and the vital role it plays in a PLN. Smartphone interactions are normally followed in preference by either face-to-face or laptop interactions. Desktop and tablet interactions are *always* the least preferred Modes. These almost universal preference patterns suggest that our PLNs are multimodal, but that our preference for specific modes is consistent across very diverse groups.

Equally, for all the subsets examined, Gathering Information was the most preferred reason for interacting with a PLN for all subsets except Childhood (who prefer Communicating and Collaborating). This was normally followed by either Searching and Browsing or Communicating and Collaborating. These three interaction purposes constitute between 69% (Childhood) and 80% (Digital Visitor) of all interactions undertaken by any sample subset. The higher this proportion, the narrower the range of interactions undertaken. Creating and Sharing and Gaming/Hobbies/Sports were almost always the least preferred reasons for interacting (except for those in Retirement, those of White ethnicity and those resident in Africa or Eastern Asia who Socialise less than they Create and Share). Again, these similar preference patterns for why diverse individuals choose to interact indicates a surprisingly high level of consistency across groups.

Turning to Human and Non-human endpoints, the majority sample subsets preferred to interact more with Humans than with Non-humans, although there was greater variation here than with the other aspects of a PLN. The exceptions to this pattern are Males; those in Retirement; those of Asian ethnicity; those living in Africa, Western Asia and Central, Southern and South-eastern Asia; those Studying; and Digital Residents. However, this only amounts to 8 of the 27 subsets that prefer non-human interactions (30%). Furthermore, in most cases, the preference was for Human and Non-human interactions almost equally (e.g. see Figs. 12.6 and 12.9)—notable exceptions being those in Childhood who much prefer Human interactions (+39%) and those in Retirement who much prefer Non-human interactions (+27%). This interaction pattern indicates the symmetry between and equal importance of the Human and Non-human actors in the network (as suggested by Actor Network Theory).

In terms of the specific Human endpoints, the results indicate a greater degree of homogeneity again. For all the sample subsets the preference was always for interactions with Friends followed by Family (except for those in Late Career and those Caring and Volunteering, who prefer Family interactions above Friends). Similarly, with the Non-human endpoints, the same range of endpoints repeatedly proved the most preferred, with just seven endpoints making up the Top-5 most preferred Non-human endpoints of all sample subsets. These were:

- Social media platforms
- Educational platforms (e.g. a VLE or MOOC provider—hence some sample bias here)
- Institutional/Organisational platforms
- Web search engines
- Forums/Chatrooms/Blogs
- Entertainment sites
- Online news

However, when it came to the actual order of preference within the Top-5 of any individual subset, there was much greater variety in preference patterns. Very broadly speaking, social media platforms were overall the most popular Non-human interaction endpoint, recorded as most preferred in 11 of the 27 subsets (41%).

In summary, clear similarities in interaction preference patterns can be seen in the device we like to choose, the reasons why we interact and the people with whom we interact. Less clear, but still observable similarities can also be seen for interaction preference with non-humans and the preference for non-human over human end-points. Overall, Network Preference shows a remarkable similarity across diverse groups.

12.6.4 HE Students

It is now possible to build up a detailed picture of the PLN of a typical HE student by combining the results for University Life Stage and Studying Main Activity in particular, along with the other shaping factors. The typical HE student has the most active PLN of any point in their life. If that student is male, he will be more active in the network than his female counterpart; if African or Asian more active than if European; if resident in Asia more active than if living in North America; if positively inclined towards technology more active than if having a negative attitude to technology. The typical student interacts most with their smartphone, followed by their laptop. They undertake most of their interactions for Gathering Information, Searching & Browsing and Communicating & Collaborating, with their preference being for interactions in that order. However, they also undertake markedly more interactions for Socialising than at any other point in life. The typical student prefers to interact more with non-humans than with humans, although this may not remain true for female students. Human interactions with Friends and Class/Coursemates are more numerous than at any other life point and more numerous than when they are working or enjoying free time. The same is true for interactions with New or Random people. The typical student will also have more interactions with social media platforms and web search engines than at any other point in life.

Furthermore, there is an observable difference when the typical student transitions from Childhood to University, and between mainly studying and mainly working. When moving from Childhood, the PLN shows a considerable increase in size and the number of smartphone, laptop and tablet interactions increase massively too. Face-to-face and desktop interactions decline. Equally, a preference for Communicating and Collaborating is replaced by Gathering Information and Searching and Browsing, while the amount of Creating and Sharing also increases dramatically. Interactions for Gaming/Hobbies/Sports declines sharply. A preference for Non-human interactions replaces a preference for Human ones. Interactions with Friends, Class/Coursemates and New or Random people increases noticeably, while interactions with Family and Teachers decline considerably. Social media platform interactions rise dramatically. Together this demonstrates the importance of mobile-friendly online learning and Social-constructivist, Connectivist and peer learning pedagogies.

In addition, when transitioning from Studying to Working, overall interactions decline and the network becomes less active. Interactions with all Modes decline, except desktop use which rises considerably. Equally, Socialising and Searching and Browsing decline sharply, while Communicating and Collaborating increases. Human endpoints return to being the most preferred interaction endpoint, while naturally, Class/Coursemate interactions fall and interactions with Work Colleagues rise dramatically. Together these changes before and after University indicate that HE students are the most active networkers of all life stages and that people and technologies are deeply intertwined in their everyday student lives (as suggested by Sociotechnical Theory).

Finally, it is interesting to consider those Modes, Purposes and Endpoints with which HE students undertake the fewest interactions. Desktops are a minor part of a typical student's PLN and Gaming/Hobbies/Sports are not popular reasons to interact. More interestingly, interactions with university teachers are very low, so too are interactions with libraries and library systems (fewer interactions than in Childhood and Retirement), presentation software, such as Powerpoint (fewer interactions than all life stages except Retirement), and writing software, such as Word (fewer interactions than Early Career and Retirement).

In summary, the PLN of a typical University student mainly involves interactions with smartphones to gather information from friends and social media. Their PLNs undergo growth, important changes to usage and shifts in interaction preference patterns on entering University. However, they are underused for important educational activities such as interacting with teachers, libraries, and presentation and writing software. This suggests potentially fertile ground for further implementing networked learning pedagogies into HE teaching and learning design. Indeed, HE Institutions and networked learning educators are critically placed to nurture and foster these PLN changes in positive educational directions, while simultaneously taking great care to mitigate the impact of any differences in size, use and preference present in the PLNs of diverse individuals. This is all the more critical since the Covid-19 pandemic and the emergency transition to online delivery.

12.7 Conclusion

The Framework for the Analysis of Personal Learning Networks presented here has helped shed robust, empirical light on the size, use and interaction preferences visible in PLNs. The *size* of a PLN is impacted by where we live, what we are doing and what we think and feel about technology, but not by our gender, stage of life or ethnic group. On the other hand, the amount of *use* we make of a PLN is much more heavily influenced by our gender, life stage, main activity and attitude to technology, but much less so by our ethnicity and where we live. The external shaping factors, in most cases, impact the number of interactions we choose to make with different devices (inc. face-to-face). They also affect the number of interactions we make for different purposes, as well as the number of interactions we choose to have with people and things.

In contrast, the interaction *preferences* we express through our PLN interactions are considerably less impacted by the six external shaping factors that were analysed. Regardless of gender, life stage, ethnicity, region of residence, main activity or attitude to technology, we tend to prefer to use devices in roughly the same ways to undertake interactions for similar purposes by interacting with similar human and non-human endpoints. In short, how diverse people from across the world build and use their PLNs shows some variation in size, considerable variation in the amount of use, but interesting homogeneity in interaction preferences.

In addition, PLNs undergo changes in size, use and preference patterns for HE students, but these changes are not necessarily for formal educational purposes. There is an opportunity here for HE institutions (HEIs) to foster network growth and use in positive ways. The results and analysis made possible by the Framework provide educators with a degree of confidence and a body of evidence to apply when designing networked learning activities, courses and programmes in the future. This is important because, in a future HE landscape dominated by ever-increasing amounts of online and blended learning, HEIs now have an increased responsibility to nurture student's use of and engagement with networks and technologies in educationally effective ways.

It is not the intention of this chapter to discuss in any further depth the implications of these findings, as the author would prefer to leave that to you, the reader. To some readers broad themes may have become visible, including the scale and extent of the sociotechnical reality in which we are embedded, the multimodality of our daily interactions, and the impact of our individual contexts on the size and use of our PLNs. Others may have found themselves thinking about the impact the results may have for teaching and Networked Learning design and how the findings can help educators to tailor networked learning activities to mitigate against some of the differences in PLNs and/or exploit some of the similarities and patterns identified, in order to provide even more effective networked learning to HE students. Many other thoughts may have occurred to many other readers too. This author would very much enjoy hearing those thoughts and would encourage you, the reader, to share them by connecting via N.S.Fair@soton.ac.uk, @nic_fair, nicfair.co.uk, or linkedin.com/in/nicfair and adding a new node to your PLN.

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