Understanding Children's Digital Maturity: A Socio-Technical Perspective[1]

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Introduction

With individuals exposed to multiple digital information and communication options the use of digital technologies has become an integral part of everyday life (Büchi et al. 2019). Mobile phones, tablets, laptops and computers are widely accepted devices to access digital information and platforms (Murphy et al. 2014). The situation among the younger population is more significant as an increasing number of children and adolescents are growing up as "digital natives". The use of Information and Communication Technologies (ICTs) is embedded in children's lifestyle, at home and for education, due to it's numerous advantages like self-learning (Markovac and Rogulja 2009), development of digital and technical competencies (McPake et al. 2005), etc. Based on a recent survey by Rideout and Robb (2020), 97% of the US households owned a minimum of one smartphone, 75% own a tablet and 44% of the children have their personal ICT device like a smartphone or tablet. Similar trends are observed in other parts of the worlds as well. 94% of the young people in EU made daily use of the internet of which 92% used mobile phones to access internet (Eurostat 2019). The Australian Bureau of Statistics of Statistics (2018) reported that 87% of Australian population was using internet of which 98% were adolescents between the ages 15 to 17 years.

This increased usage of digital technologies by children have raised serious concerns about its impact and influence on multiple aspects of children's lives ranging from their level of physical activities, ability to interact with others in 'real-life' to mental and physical health problems (Winther et al. 2017). Restrictions, regulations and strict stay-at-home orders during and post COVID-19 pandemic aggravated the over-use of digital devices by children for various

[1] *The bulk of the work was done by a student*

day-to-day activities primarily because of school, education and sometimes socializing (Pandya and Lodha 2021). Where regulated and mindful use of digital technologies is linked to individual well-being, impulsive, compulsive and unregulated use of digital technologies has reported to be associated with certain negative physical and mental health problem (Allen et al. 2019, Rahman et al. 2020). According to Lissak (2018), excessive screen time is associated with poor sleep and risk for cardiovascular ailments like high blood pressure, poor stress regulation and obesity in children along with impaired vision and reduced bone density. Psychological effects associated to high screen time induced depressive and suicidal symptoms and poor sleep (Lissak 2018). Lissak (2018) also found that anti social behaviour and decreased prosocial behaviour in children were linked to early and prolonged exposure to violent contents. Anxiety and depression was found to be linked with increasing cyber-crimes and cyber-attacks during to pandemic (Lallie et al. 2021) Moreover, researches have also found evidence of behavioral addictions like gambling associated with problematic use of social media on mobile devices (Henzel and Håkansson 2021).

While multiple studies report and focus on the potential advantages and benefits of using digital technologies by children like psychological benefits, improved learning process, and improved social skills for children with special needs (Jackson et al. 2008, Livingstone 2012, Frauenberger et al. 2011), there are numerous studies that highlight the negative effects of digital technologies on children like increased rates of mental health problems in teenagers with heavy usage of smartphones and social media (Odgers and Jensen 2020). Despite such contrasting results, the universal understanding remains that the use of digital technologies by children is continuously evolving (Livingstone et al. 2018) hence there is an increased need for more researches in understanding children's behavior and their use of digital technologies (Bell et al. 2015).

The purpose of this study is to investigate how children use digital technologies, focusing at identifying different maturity levels in children based on their interactions with digital technologies. In this study, 'Digital Maturity' refers to "the overall ability of children to assess and regulate their behaviour on when, how and in which context the use of digital technologies is either beneficial or harmful to them" (Arenas and Yazdi 2022). Therefore, we address the following research questions: *Are there common patterns in children's ICT usage?* and *Can we predict the digital maturity of children from their ICT usage patterns?*.

To date, there is a scarce comprehensive understanding of children's ICT usage. Multiple researches focus on the usage of ICTs by children concentrate broadly on the impact on educational performance of preschool and primary school children (Kerckaert et al. 2015, Aesaert et al. 2015) or social media use and its consequences on attributes like reading and academic performances (Hu and Yu 2021, Agosto and Abbas 2010, Luo et al. 2020, Vanderlinde et al. 2014) or behavioural and helath factors like compulsive use, obesity, sleeping habits, etc. (Dhir et al. 2016, Kautiainen et al. 2005, Punamäki et al. 2007). The literature also instantiate that parents are concerned about the increasing use of ICTs by their children and their socio-emotional development (Danet 2020). There is no systematic, data-driven and comprehensive understanding about how children use ICTs and what it means for their overall maturity.

To find answers to these questions we adopted the design science paradigm to guide the development of an IT artifact. We design an IT artifact calibrated with real-world data of children aged between 9 to 18 years from Austria and Germany. At the core of this artifact lies a machine learning algorithm to identify categories of children with distinct digital maturity. Germany and Austria provide an interesting context for this research however, our design science approach can be calibrated with data form other countries, without loss of generality. 89% of the German teens use internet on a daily basis of which 93% used their smartphone daily with an average daily internet usage time of 241 minutes (Koptyug 2021). In Austria, around 90% of children aged between 11 to 18 access digital technologies on a daily basis (Orde and Durner 2021).

This study contributes to the existing IS literature in the numerous ways. First, we identify systematic similarities among children based on their ICT usage and interpret them with a psycho-social context. We translate the digital usage behavior of children into meaningful interpretations for the relevant stakeholders like parents and teachers. There is scarce evidence of research within IS literature that tries to understand the heterogeneity of ICT usage patterns within young children and adolescence. Second, we build a predictive machine learning model that uses behavioral characteristics of children, to classify them into different maturity levels. Researches have shown that more than half of the parents are concerned about their children's screentime and about 63% parents consider that the use of ICTs at home affects their relationship with their child (Danet 2020). Having a predictor that classifies children based on their ICT usage would be of extreme importance to parents as it would provide them with meaningful insights of the kind of interactions their child has with digital technologies and how much are they affected by it behaviorally. Moreover, it has serious implications for schools where teachers would be able to identify some particular/peculiar behavior of children just by knowing their digital maturity level. We use the DSR paradigm in this study to create the IT artifact that categorizes children based on their ICT usage patterns and consequently predicts children's digital maturity. We also contribute to the socio-technical literature within IS domain in the category 'The Social and the Technical as Producing Outcomes Through Their Interplay' since we are investigating the relationship children share with ICTs in terms of its usage (Sarker et al. 2019). Furthermore, the research also has a set of practical implications ranging from making informed decisions to design school programs for inculcating effective ICT usages that could result in better digital education and schooling systems, to policies and regulations encouraging healthy digital habits.

We first provide a review of the literature on models of psychosocial maturity and socio-technical perscpective in IS research followed by the explaination of our IT artifact. The latter section explains the methodology where we elaborate our discussion on the data and digital maturity. Next we present our results and discuss relevant implications. Finally we conclude the discussion with contributions, limitations and future direction of the research.

Literature Review

In line with the DSR guideline "Design as a Search Process" (Hevner et al. 2004), this study uses the concept of children's digital maturity (Arenas and Yazdi 2022) which builts on the literature of psychosocial maturity and is used in a digital context. The psychosocial maturity literature integrates a person's socialization and individual development goals. Also relevant to this study is the Socio-Technical Perspective of IS research since it conceptualizes the social and the technical, as two mutually interacting components which in our case is the interaction of children with ICTs, who attempt to solve their problems, achieve one of their goals or serve one of their purposes through ICT interaction (Lee et al. 2015). The socio-technical view attributes equal importance to both the technical and the social components, acknowledging the interdependence between them, and focusing on a fit between the two components (Sarker et al. 2019). By this research we believe that we inch a step closer to achieve a 'fit' optimization of ICT usage by children as a socio-technical perspective would help us attain an effective instrumental humanistic outcome (Sarker et al. 2019). We use the design science paradigm provided by Hevner et al. (2004) as the overall framework of our research.

Psychosocial Maturity

The first multi-disciplinary model of psychological and social development, based on the idea of 'psycho-social' maturity, was depicted by Greenberger and Sørensen (1974) and Greenberger et al. (1975) that seeks to integrate individual's development goals with socialization goals (Khatibi and Sheikholeslami 2016). According to Greenberger et al. (1975), psychosocial maturity reflects in three capacities: *i) Individual Adequacy*: The capacity to function effectively on one's own, *ii) Interpersonal Adequacy*: The capacity to interact adequately with others, *iii) Social Adequacy*: The capacity to contribute to social cohesion. In essence, "psychosocial maturity can be described as the ability to take on obligations and make responsible decisions by considering one's own needs and the consequences of one's own actions" (Khatibi and Sheikholeslami 2016). According to Khatibi and Sheikholeslami (2016) the scientists' technique to measure psychosocial maturity evolved in the late 1990s. Steinberg and Cauffman (1996) suggested that during adolesence and early adulthood, three aspects of psychosocial maturity develop - *i) Temperance* (ability to inhibit impulsive and aggressive behavior) , *ii) Perspective* (the ability to see things from diverse point of views) and *iii) Responsibility* (the ability to function autonomously).

The lens of psychosocial maturity has been used to understand diverse kinds of behaviours in children including antisocial behaviour, risk taking behaviour, communication skills and decision-making, etc. (Arenas and Yazdi 2022, Pailing and Reniers 2018, Monahan et al. 2009, Cvetkovich and Grote 1981). However, not much literature exists in context to digital technologies and psychosocial maturity. Wang (2001) analysed internet dependency and psychosocial maturity among college students and found no direct relation between internet dependence and psychosocial characteristics, exclaiming the need to include sociocultural variables for the analysis of such relations. Taking into account young children's developmental processes, it is sufficiently reasonable to assume that children's online behaviour closely resembles their offline needs (Arenas and Yazdi 2022, Steijn 2014).

Based on the above discussion and in accordance with Arenas and Yazdi (2022), we consider digital maturity as '*a dynamic concept that develops over time which includes the ability of children to assess and regulate their behavior on when, how and in which contexts the use of mobile ICTs is either beneficial or harmful to them*'.

Socio-Technical Perspective

The socio-technical perspective in Information Systems is considered as one of the foundational view points of this discipline, contributing to both its distinctiveness and its ability to coherently expand its boundaries (Sarker et al. 2019). According to Sarker et al. (2019), "The socio-technical perspective considers the technical artifacts as well as the individuals/collectives that develop and use the artifacts in social contexts (Briggs et al. 2010)." This perspective neither favors the technical nor the social and explicitly acknowledges the interdependence between them (Bostrom et al. 2009) while focusing on the fit between the technical and social components (Pava 1983, Wallace et al. 2004). A fit optimization between the technical and the social components is expected to result in better instrumental and humanistic outcomes.

The Design Science Approach and IT Artifact

Figure 1 represents the design of our IT artifact. By definition, a purposeful IT artifact addresses an important organizational/societal problem (Hevner et al. 2004). Abundant literature indicates that there are significant negative consequences of unregulated ICT usage by children, be it mental or physical health, and there are scarce evidence that helps us better understand these effects at a granular level. Hence, we identify the effect of increased use of technologies by children as our primary problem and therefore in this research, we build an artifact that gets inputs from children aged 9-18 years, clusters them in groups based on their ICT usage patterns and further predicts children's digital maturity. This artifact has substantial implications to parents regarding what Digital Maturity means for their children and consequently for schools and educators as it makes behavioral predictions based on technology usage patterns. Our IT artifact contains three blocks: (1) Input, (2) Processing and (3) Output.

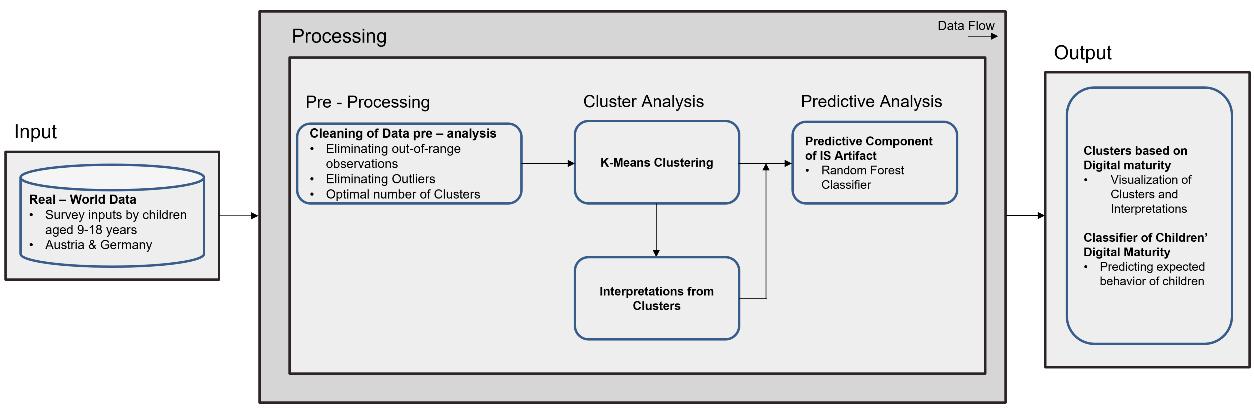

Figure 1. Design of IT Artifact

Input Block

Gathering knowledge from the field of psychology to understand the dimensions of psychosocial maturity and using it in the digital context, a survey was designed that was used to collect the real-world data. Using this survey, data from children aged 9-18 years was collected from Austria and Germany which was used as the input to the machine learning algorithm. The data contained answers to questions pertinent to the identified dimensions of digital maturity along with information on the total usage of digital device per week and some demographics.

Processing Block

Within this block we have 4 units. The first unit is the pre-processing unit in order to clean the data. We eliminated the data points that were beyond the target age of 9-18 years followed by the elimination of outliers using Isolation Forest which identifies and isolates outliers using a decision tree model. With this clean data, we investigated the optimal number of clusters for our analysis. We emulated the procedure suggested by Koehly et al. (2001) and began with hierarchical clustering to observe the cluster structure at separate levels. We finalized the Bayesian Inference Criteria (BIC) that gave us 3 as the optimal clusters. BIC searches over a range of different types of Gaussian Models to find the best model estimate via Expectation Maximization algorithm for model-based clustering, classification, and density estimation. This criteria is widely used in unsupervised learning to determine clusters of varying size, temporal clusters and specifically K-means clusters (Xie et al. 2009, Molinari et al. 2001, Sinaga and Yang 2020)

Next, for the analysis of data, we used K-Means clustering algorithm on our datasets which resulted in 3 distinct clusters for Austria and Germany. Once the clustering was complete, the results were used to build a Predictive classifier. The reason clustering was performed prior to the predictive model was because we were missing out on the 'ground truth'. There was no possible way to know the levels of children's digital maturity beforehand. In the absence of an absolute ground truth, making predictions is nor possible hence our identified clusters, corresponding to each observation, served as a proxy for ground truth to make predictions. We used the random forest technique to build our classifier (Biau and Scornet 2016). Once we had a basic model, its hyper-parameters were tuned to give a more accurate and robust result.

Output Block

The output of the presented artifact is the classification of new data entries based on their digital maturity. The model has prediction capabilities and helps predict digital maturity of children based on their device usage.

The above described artifact is currently at a demo phase and will be deployed as a standalone application on the IBM Cloud and soon be publicly available. The artifact currently works on evaluation of the data available from the Austria and Germany, however, in due course of time, new data will be fed in the system, and with continuous iterations over the new data, the model will increase on its current accuracy.

Data

With an aim to have a clear understanding of children's digital maturity, a comprehensive background of children's digital maturity regarding ICT use patterns, socio-demographics, risk perception, digital literacy and personality characteristics were collected.

As shown in Table 1, it was found that 9 important competencies and responsibilities contribute towards Children's Digital Maturity (Laaber et al. 2022). [2] These 9 'dimensions' are : *Digital Literacy, Risk Awareness, Individual Growth, Respect Towards Others, Digital Citizenship, Support Seeking Behaviour, Autonomy Within Digital Context, Autonomy of Choice* and *Regulation of Negative Emotions*.

Table 1. Dimensions of Digital Maturity

Dimension Name	**Definition**
Digital Literacy	The technical skills to use mobile devices and the internet in a safe and effective manner
Risk Awareness	Managing risks related to mobile devices and the online environment by being aware of potential dangers and influences
Individual Growth	The ability to use mobile devices and digital contexts for personal learning and growth
Respect Towards Others	Acting respectfully when engaging with others and in content one shares online
Digital Citizenship	Using mobile devices and digital contexts to contribute to society and support important causes
Support Seeking Behavior	The ability to seek support from others when encountering problems regarding mobile devices or digital contexts
Autonomy Within Digital Context	Deliberately choosing which digital contexts to engage with, viewing content which one finds interesting and enjoys
Autonomy of Choice	Using mobile devices out of one's own choice rather than a feeling of obligation or compulsion
Regulation of Negative Emotions	The ability to control and effectively regulate negative emotions due to frustrations in digital contexts

The data comprised of 603 observations from Austria and 406 observations from Germany. After the elimination of outliers, 555 observations for Austria and 378 observations for Germany remained.

Method and Evaluation

We used K-means clustering on the Austrian and German datasets separately to identify initial clusters of children based on their ICT use. Drawing from the limitations of K-means clustering methods, one of the challenges was

[2] This part of the research was conducted by another teams in the project who designed the survey and performed the required reliability and validity checks.

elimination of outliers. To remove them *Isolation Forest* (IF) anomaly detection algorithm (Liu et al. 2008) was used. After running the Isolation Forest on both our datasets, we removed the top 5% of the anomalies and continued the analysis.

K-means clustering requires the determination of the number of clusters to emerge from the data. To determine the optimal number of clusters, we resorted to the Bayesian Information Criteria (BIC) (Hofmeyr 2020). The BIC finds Gaussian Mixture Models estimated via Expectation Maximization algorithm for model-based clustering, classification, and density estimation. It searches over a range of different types of Gaussian Models to find the best model that is the optimum number of clusters in our case. We use this criteria for its following benefits: *i)* Any continuous density can be represented by a mixture of Gaussians to a given degree of accuracy, *ii)* relatively parsimonious representation of structures and *iii)* good density estimates in reasonably high dimensions. We ran the BIC on both our datasets and found out 3 as the optimal number of clusters for both Austria and Germany. Figure 2 shows the BIC Plots for Austria and Germany to illustrate the optimal number of clusters for each dataset.

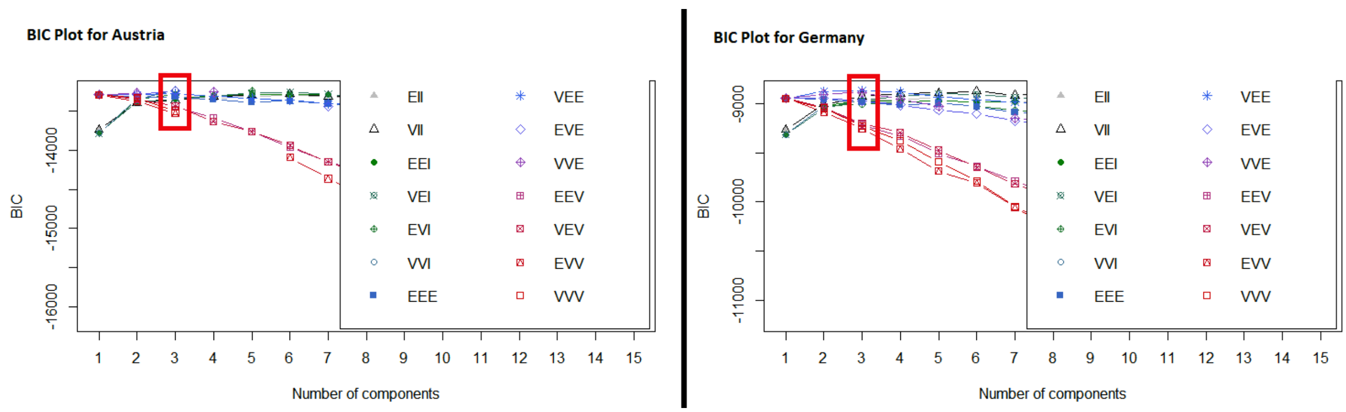

Figure 2. BIC Plots for Austrian and German Dataset

Predictive component of the IS artifact

With the results obtained for our initial clustering, we build a classifier that, based on the child's digital maturity, classifies new children into one of the identified groups. For the prediction task, we chose random forest for its many advantages (Devetyarov and Nouretdinov 2010) as it *i)* produce high accuracy for multiple data sets, *ii)* can process data with a large number of features and *iii)* is robust to mixed variable types, missing data, outliers and noisy data.

With the target or the variable to be predicted as Groups (the identified clusters), features (Independent Variables) as all the 9 dimensions, we build our predictive model. The accuracy of our model was 90%.

Results and Discussion

Our primary focus is to identify clusters of children with different digital maturity levels Austria and Germany. We identified three clusters each for the two countries. The descriptive statistics for each cluster can be seen in Table 3. Some basic observations from Table 3 suggest that there is no trend of children's age that may play a significant role in determining their digital maturity, the average age of all the identified groups in both the countries is more-or-less similar. We also observe an almost uniform distribution of males and females in all the clusters for the two countries. We plotted the digital maturity dimension score of these three cluster groups against their mean z-score and identified some peculiarities in each group while some similarities amongst groups at the same time.

Table 2. Descriptive Statistics for Obtained Clusters

	Cluster	Number of Members	Average Age *(Years)*	Total Device Usage *(Scaled Score)*	Male	Female
Austria	Group 1	165	15.46	-0.294	79	86
	Group 2	171	14.83	-0.356	88	83
	Group 3	220	15.13	0.529	125	95
Germany	Group 1	99	15.46	0.314	52	47
	Group 2	148	15.35	-0.693	75	73
	Group 3	131	14.95	0.554	60	71

It is evident from Figure 3 & 4 that out of the three groups for Austria and Germany, one group of children is indicative of having lower digital maturity since scores of almost all the dimensions are much below than their respective mean values. This is group 3 in both the countries. Interestingly, this group is observed to have the highest overall usage of digital devices in a week. We therefore term this group as *'Low Maturity with High Usage'* group. Of the remaining two groups, we observe a group that seems to be opposite to the above mentioned group in terms of their digital maturity scores. This group (group 1 in both countries) appear to have a high digital maturity as the scores of almost all the dimensions is much higher than their respective averages. Looking at the total usage of digital technologies by children in this group, we see they have a medium/moderate use as compared to the other three groups. We term this group as *High Maturity with Moderate Usage* group. For the remaining group we see that the children have above average score for some dimensions and below average for the other. The children in this group seem to exhibit average/medium digital maturity when compared with other two groups. The children in this group have the minimum total usage of digital devices as compared to the other groups hence we term this group as *Average Maturity with Low Usage* group. The following section discusses a more detailed overview of the three cluster groups that we mentioned above for Austria and Germany.

Clusters for Austria

High Maturity with Moderate Usage Group:

The children in this group clearly have the maximum digital maturity score as compared to the other two groups. Children in this group have a positive mean z-score in all the dimensions which means children from this group, on average, are above the mean distribution in all the dimensions of digital maturity. The dimension with the highest value in this group is Individual Growth indicating the children belonging to this group learn new skills online, followed by Risk Awareness, Respect Towards Others, Digital Citizenship & Digital Literacy implying that children are careful using digital devices, are respectful to the online community, support campaigns regarding environmental issues and are aware of privacy & content settings of websites respectively. Children in this group are moderate in regulating their negative emotions and do not exhibit significant impulsive behavior while using digital technologies.

From a psychosocial point of view, we observe that children clustered within this group perform well in all the capacities under review. According to Greenberger and Sørensen (1974) such 'mature members of a social system' are characterized by effective individual functioning, effective social relationships and self maintenance . In digital context, such characteristics attribute to effective digital learning at an individual level, effective social behaviour in the online community and adherence to digital and societal norms while operating digital technologies. The moderate usage of digital technologies also indicate higher social well-being (Belton et al. 2021). Considering the current research scenario where majority of the research focuses on the negative impacts of digital technologies on children, these findings strongly suggest that there is a group of digitally mature children who have a responsible attitude towards the use of technology at the individual and community level. For parents and educators, the results indicate that introducing children to productive ways of using technology helps them overcome the negative effects of misuse or overuse (Yücelyiğit and Neriman 2021).

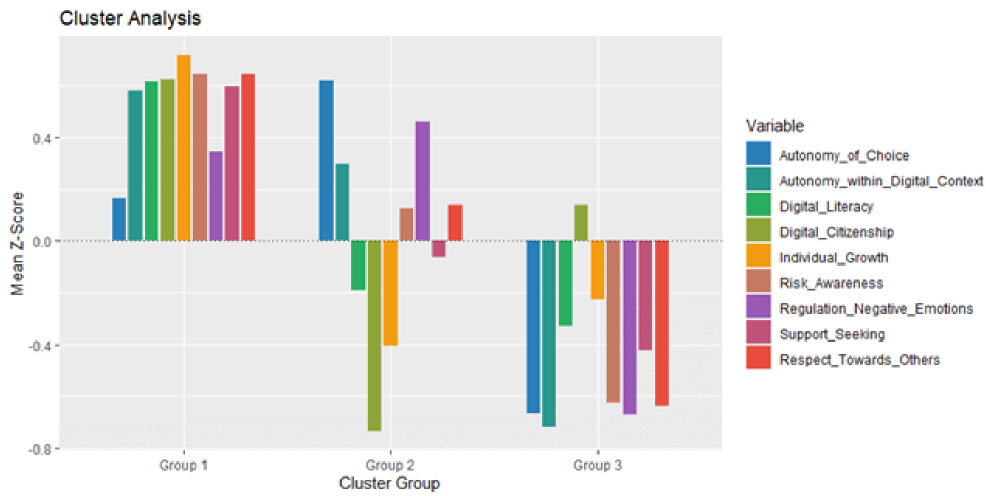

Figure 3. Clusters Obtained from Austrian Dataset

Average Maturity with Low Usage Group:

Unlike the High Maturity with Moderate Usage group, this group has a lot of variation in terms of the dimension's mean z-score. We observe 5 out of the 9 dimensions on the positive side and 4 having negative values of mean z-score. On the positive side of the graph, we see the dimensions Autonomy of Choice, Regulation of Negative Emotions and Autonomy Within Digital Context indicating that the children in this group do not exhibit impulsive behaviour while using digital devices and are good at controlling their negative emotions that are caused by online interactions. On the negative side of the axis, the 4 dimensions are Digital Citizenship with a very large and negative z-score implying that the children in this group do not really support environmental issues or stand-up for what they think really matters in the world. Individual Growth, Digital Literacy & Support Seeking Behavior dimensions also have a negative value signifying children do not learn new skills from digital devices, are unaware of privacy and content settings of websites and do not seek support of elders/peers when encountering problems online and with digital technologies.

From the lens of psychosocial maturity, we see that the dimensions corresponding to both individual growth (Digital Literacy, Individual Growth) and socialization (Digital Citizenship) and much below the average score indicating lower psychosocial maturity. For socio-economic development of the digital society and employability of the future labour force, digital skills and digital literacy play an integral role and in the absence of these competencies, it is not possible for children to participate well in the digital society and it also affects the way people live and communicate (Bejaković and Mrnjavac 2020). According to Purnama et al. (2021), negative self-control behaviour is reported in children with low digital literacy abilities. Moreover, they also tend to be suspects or victims of cyber-world crimes and tend to have impulsive characteristics, sometimes influencing their attitudes in behaving online and offline (Purnama et al. 2021).

Low Maturity with High Usage Group:

In this group we observe the least digital maturity score with 8 out of 9 dimensions' mean z-score lower than the mean of the sample. The only dimension with a meager above average score is Individual Growth indicating that children learn something new and useful. Strikingly, this group has the highest overall usage of digital technologies but we observe large negative z-score values for almost all the dimensions forming this cluster. Autonomy Within Digital Context has the poorest score followed by Autonomy of Choice and Regulation of Negative Emotions clearly indicating impulsive/addictive behavior towards the use of digital devices while not being able to cope, in 'real-life', with the distress caused virtually. Respect towards others is also seen to have low mean z-score.

From a psychosocial point of view, the children in this group exhibit poor digital maturity while using ICT devices. Low psychosocial maturity is associated with lower cognitive capacity in adolescence (Icenogle et al. 2019), higher risk of engaging in crimes (Fine et al. 2018) and lack of empathy, deficient guilt or remorse, and shallow affect (Simmons et al. 2020). Such attributes when translated to digital context would translate to cyber-bullying, online harassment and in extreme cases cyber-crimes. Children belonging to this group would be an easy prey to all such activities. Moreover, there is evidence that activities like cyber-stalking and cyber-bullying significantly affects students' academic performance (Al-Rahmi et al. 2020).Additionally, since this group has the highest digital device usage, researches prove that higher screen-time can increase the risks of mental health problems and poor sleep quality among students (Wu et al. 2015). Excessive use of social media modifies teenagers' sleep-related behavior which increases with increasing age (Royant-Parola et al. 2017). Hence, extra attention needs to be given to the children clustered in this group when they interact with digital technologies.

Clusters for Germany

High Maturity with Moderate Usage Group:

Similar to the High Maturity with Moderate Usage group in Austria, we observe this group in Germany with 7 of the 9 dimensions having a positive mean z-score implying children have above average score in these 7 dimensions. Within the 3 groups we see in Germany, this group exhibits the highest digital maturity with maximum Digital Literacy and Digital Citizenship implying good awareness about website's privacy settings and supporting important environmental campaigns. The two dimensions with lower than average score are Autonomy of Choice and Regulation of Negative Emotions suggesting partly impulsive behavior and slightly lower capability to overcome 'techno-stress'.

From a psychosocial perspective, the children clustered in this group exhibit higher level of individual and social maturity as they have the higher ability to use ICTs for personal learning and growth (Individual Growth) and use ICTs to better contribute to the society (Digital Citizen). These attributes enables one to take sensible decisions and participate actively and positively in community affairs (Ferrari and Punie 2013). Moreover, digitally literate children benefit largely from internet platforms whilst simultaneously avoiding online risks associated with Internet usage (Sonck et al. 2011, Staksrud et al. 2013). Lack of autonomy of choice, which is observed in this group, has been linked to undermine well-being of an individual in a digital context, affecting education and creates a risk of moral panic (van der Willigen 2020).

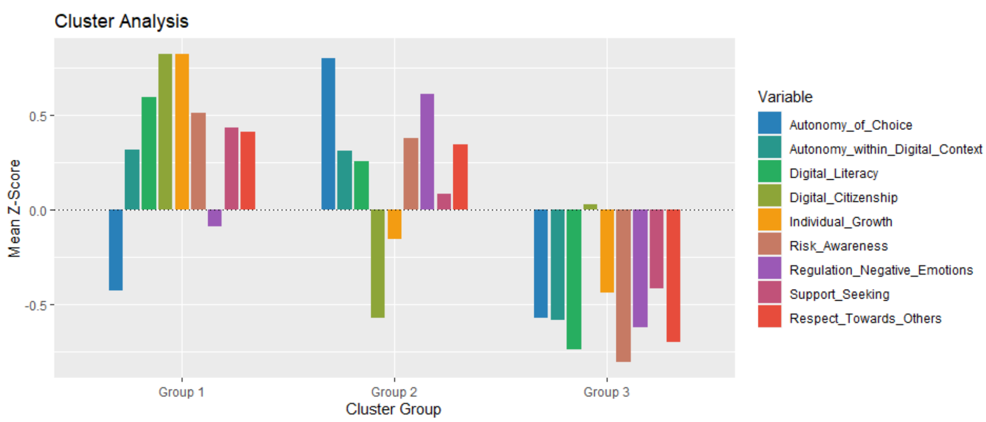

Figure 4. Clusters Obtained from German Dataset

Average Maturity and Low Usage Group:

In this group again we see that 7 out of 9 dimensions score a value higher than mean but as contrast to the previous group, the range of scores is much wider. The two dimensions in this group whose score is below average are Digital Citizenship & Individual Growth. The children in this group score the highest for the dimension Autonomy of Choice and also score well in Regulation of Negative Emotions.

Interpreting these findings from a psychosocial perspective, we see that the children in this group lack the ability and awareness to contribute to the society in a safe and effective manner with their ICT usage (Digital Citizenship) and use ICTs for personal learning (Individual Growth). Digital citizenship behavior has been used to describe online civic engagement of adolescents and is negatively related to online harassment perpetration (Jones and Mitchell 2016). This may be attributed to the fact that the overall usage of digital technologies within this group is low and the children lack the overall awareness of healthy ICT usage. Having low individual growth along with low digital citizenship may hint towards inability to cope with social dynamics of the digital society implying a potential digital divide.

Low Maturity with High Usage Group:

As compared to the other two groups, we can say that the children in this group have the least digital maturity score since they have a below average score on 8 out of 9 dimensions. The only dimension with an above average score is Digital Citizenship with a score of 0.03 above SD, which in itself is very close to the mean indicating awareness and conciseness towards important environmental and societal issues within children of this group. The children in this group score the least in Risk Awareness implying very low sense of personal safety and carefulness while online. The scores of other dimensions of the children in this group indicate impulsive/addictive behaviour while using digital technologies, low ability to cope with online stress, below average awareness of privacy settings of websites and low individual growth in terms of learning new things and acquiring novel skills. Moreover, this group is also characterized with maximum overall usage of digital devices which makes them prone to additional well-being related issues like anxiety, depression, psychopathological behaviour (Dienlin and Johannes 2022)

The children clustered in this group have very poor psychosocial maturity in digital context.They indicate impulsive ICT usage and connote lack of ability to use digital technologies and poor self learning. Lack of risk awareness in a digital context indicates potential maladaptive behaviours in children that do not necessarily guarantee their positive psychological development (Gui and Büchi 2021).

Overall, looking at the results from both the Austrian and German datasets, we broadly identified three different clusters of children based on their digital maturity and total usage of digital devices. There is one group of children that is suggestive of being psychosocially mature with their interactions with digital technologies. Children in this group exhibit individual, interpersonal and social adequacy along with temperance, perspective and responsibility attributes that make them digitally mature than others.They also have a comparatively moderate time usage of digital devices.

There is another group that is completely opposite to this digitally mature group, the one where children exhibit impulsive characteristics, lack of risk awareness and individual growth, and in general, absence of digital well-being. To make matters worse, this group is observed to have the maximum time usage of digital devices. The third group that we identified is in between this continuum of digital maturity. Results disclose that children in this group show autonomous behavior while using digital technologies, regulation of negative emotions and fair awareness of risk pertinent to digital technologies. What's also interesting to see is that children in this group appear to have low digital citizenship behavior and lack of individual growth indicating low social and individual adequacy. We also observe that this group has the least usage time interacting with digital technologies.

Conslusion

With this research, we aimed at closely investigate how children use digital technologies specifically to identify different maturity levels in children based on their ICT usage patterns. We used the lens of psychosocial maturity in a digital context and the concept of digital maturity along its 9 dimensions to determine the groups of children based on their ICT usage behaviour. This complies with the design science guideline, "*Design as a search process*". For our first research question *Are there common patterns in children's ICT usage?*, we found that based on the nine dimensions that contribute towards the digital maturity of children, children can be categorized into groups according to their ICT usage. We found this using robust K-Means clustering. For the question about predicting the digital maturity based on children' ICT usage pattern, we used supervised machine learning to build a model that uses random forest classifier. The model predicts with an accuracy of 90%.

These results contribute significantly in the use of ICT by children literature since there is, to the best of our knowledge, no research which employs data-driven techniques on real-world data that clusters children based on their ICT usage behavior. We identify three distinct digital maturity groups. The High Maturity with Moderate Usage group exhibit high psychosocial well-being in terms of their interactions with digital technologies as they seem well-aware of their actions and consequences online, are respectful to individuals and society while online and have good self-control over their negative emotions and overall technology usage. The Average Maturity with low usage group has children that have above average self-control over their digital technology usage indicating autonomous behaviour in digital context and are fairly aware about the online risks and have respect towards individuals in online communities. The reason they lack digital citizenship and individual growth capabilities can be attributed to the fact that their overall usage of digital technologies is the least. The Low Maturity with High Usage group clusters children with poor psychosocial maturity who are more prone to cyber-crimes, cyber bullying and online harassment owing to their impulsive technology use patterns, lack of digital risk awareness and high overall technology usage. Since children in this group have the highest overall technology usage, these children are more prone to poor well-being.

The implications of this study are noteworthy for parents and educators since it enables them to understand children's behavioral attributes based on the kind of interactions they have with digital technologies. The information derived from this model could be used by parents who sometimes struggle to identify underlying factors of their children's deviant behavior when they deal with 'real-life' situations. For example, if a child is classified in the Low Maturity with High Usage Group, knowing that one of the characteristics of the children belonging to this group is low 'Support-Seeking Behaviour', an easy accomplishment for parents and/or teachers could be to discuss or talk about and educating the particular child about the difficulties and problems they are facing while interacting with digital devices. Parents can play a defining role in reducing their children's screen time by enhancing the overall environment of their homes, improve kinship amongst family, and regulating screen time (Sultana et al. 2021).

Even schools could benefit from these findings as they would allow schools to understand children from the dimensional perspective of digital maturity and could design programs in ways that promote higher digital maturity within children. For instance, if a bunch of children are found to be grouped in a particular digital maturity group, based on their characteristics, corrective/educative measures could be taken in the direction that would incline the group towards a more digitally mature behavior. Governments can deploy training and support programs for parents and teachers that could help guide children at home and at school. With the use of data and statistics, governments can increase parents' and teachers' awareness about affects of screen time via social media campaigns/advertisements, webinars, and other media forums. Training modules can be designed for them to improve household and in-school supervision to better guide children.

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