

Cyberbullying Victimization among Adolescents: Machine Learning Analysis of Survey Data

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Abstract: Cyberbullying has emerged as a pervasive issue affecting children and adolescents globally. This research article aims to empirically explore the prevalence of cyberbullying among adolescents in the U.S., elucidating its various forms and manifestations, and adolescents' perception of cyberbullying victimization. It also examines the adolescents' views of the cyberbullying risks and the potential protective factors. This study is based on quantitative data collected through survey interviews with 380 adolescent children aged 12-17 years living in the Hampton Roads area in Virginia, U.S. Three machine learning models, a Principal Component Analysis (PCA) model, a decision-tree model, and a K-Nearest Neighbors (KNN) model, are processed to examine the patterns in their cyberbullying experiences. The deciding factors that impact adolescent children's perception of cyberbullying victimization are also analyzed. This study contributes to shedding light on understanding cyberbullying experiences among adolescents by highlighting the adolescents' perception of cyberbullying victimization and what they think would be effective measures to help avoid cyberbullying.

Keywords: Adolescents, Cyberbullying, Victimization, Machine Learning, Survey

Introduction

With the proliferation of digital technologies and the increasing accessibility of online platforms, children are becoming more vulnerable to cyberbullying and the profound effects of cyberbullying on their well-being and healthy development. Defined as the deliberate and repeated harm inflicted on an individual using electronic devices, cyberbullying is "an aggressive, intentional act" that can be carried out by "a group or an individual" and the victim of cyberbullying always finds it very hard to "defend him or herself." (Smith, Mahdavi, Carvalho, 2008). Cyberbullying among children has become a universal issue worldwide. It has emerged as a pervasive issue affecting children and adolescents globally. For example, Hinduja and Patchin (2020) conducted a meta-analysis and found that approximately 32% of students worldwide have experienced cyberbullying and traditional bullying at some point in their lives. Similarly, a meta-analysis conducted by Modecki et al. (2014) found that the prevalence of cyberbullying victimization among children ranged from 5% to 35% across studies.

Cyberbullying can take various forms, including harassment, flaming, cyberstalking, denigration, and exclusion (Wang, Iannotti, & Nansel, 2009). The inescapable nature of technology in children's lives means that cyberbullying can occur at any time and place, vastly expanding the traditional arenas of bullying. This ubiquity

makes it difficult for victims to find relief and contributes to the potentially severe impact of cyberbullying on young individuals. It often occurs through social media platforms, text messages, emails, online forums, and gaming communities. Harassment involves sending mean or threatening messages, while exclusion entails intentionally excluding someone from online groups or activities. Rumor spreading involves disseminating false or hurtful information about an individual, and impersonation involves pretending to be someone other than yourself online to harm or deceive others.

Research suggests that gender differences exist in the prevalence and nature of cyberbullying experiences among children. While both boys and girls are vulnerable to cyberbullying victimization, studies indicate that girls are more likely to experience relational forms of cyberbullying. Due to the anonymity provided by digital platforms, this may encourage more indirect forms of aggression, which are more prevalent among girls. These forms include spreading rumors, exclusion, and the malicious sharing of personal information. The nature of these attacks often relates closely to social relationships and emotional manipulation, which can be particularly damaging to the social fabric of girls' lives. Conversely, boys are more often involved in cyberbullying both as perpetrators and victims of more overt and direct forms of aggression, such as threats and harassment. The study by Wang et al. (2009) suggests that while boys may engage more in cyberbullying activities, they are less likely to perceive these actions as harmful or to report impacts on their mental health. This could be attributed to societal norms that encourage a more stoic demeanor in males, discouraging them from expressing vulnerability. These gender differences may have implications for the design and implementation of interventions targeting cyberbullying prevention and support.

There are notable differences in how cyberbullying is reported and perceived across different groups, influenced by age, gender, and cultural factors. Younger children may not always recognize certain actions as cyberbullying, or they might not report them due to fear of reprisal or losing access to their digital devices. Adolescents, facing intense peer pressure and the desire for social acceptance, might also underreport experiences of cyberbullying. Cultural factors also play a significant role. In some cultures, certain behaviors may not be perceived as bullying due to differing norms about communication or confrontation. Additionally, variations in parental and educational responses to cyberbullying can influence both the prevalence and the reporting of such incidents.

The detrimental effects of cyberbullying on children's mental health are well-documented in different studies and literature. It also appears to diverge along gender lines. Research indicates that victims of cyberbullying are at increased risk of experiencing various psychological problems, including depression, anxiety, low self-esteem, and suicidal ideation (Bauman, Toomey, & Walker, 2013; Kowalski & Limber, 2007). Girls tend to report higher levels of emotional distress and are more likely to experience anxiety and depression because of cyberbullying. This vulnerability is partly due to the nature of the bullying experienced by girls, which often targets their relationships and social status, which are areas highly valued by many adolescent girls. Boys, while also negatively impacted by cyberbullying, often exhibit different psychological responses. They may be more likely to externalize problems through aggression or delinquency. Additionally, the reluctance among boys to report or discuss experiences of cyberbullying can lead to a lack of adequate support, thereby exacerbating feelings of isolation and anger. Furthermore, cyberbullying can exacerbate feelings of social isolation and loneliness, leading to further deterioration of mental well-being (Tokunaga, 2010). These feelings can escalate into clinical depression if left unaddressed. The persistent nature of cyberbullying, facilitated by digital platforms where messages and images can be spread widely and quickly, can make these

experiences particularly traumatic. A longitudinal study by Sourander et al. (2010) found that adolescents who were victims of cyberbullying were more likely to develop depressive symptoms over time compared to their non-bullied peers. Anxiety is one of the depressive symptoms that could develop because of cyberbullying, with victims frequently feeling in a state of constant fear of further victimization. This anxiety can be widespread, affecting not only the child's online interactions but also their overall sense of security, extending into offline areas of life. Such chronic stress can exacerbate or lead to anxiety disorders, significantly impairing the child's daily functioning and well-being. The anonymity afforded by online platforms can intensify the psychological distress experienced by victims, as they often feel powerless to confront or mitigate the abuse (Patchin & Hinduja, 2010).

Additionally, cyberbullying can have long-term consequences on children's emotional development and academic performance. Research indicates that victims of cyberbullying are more likely to exhibit academic difficulties, absenteeism, and school avoidance, further exacerbating their distress (Klomek et al., 2007; Ybarra, Diener-West, & Leaf, 2007). The pervasive nature of cyberbullying means that its impacts can extend beyond the confines of the virtual world, permeating into children's daily lives and interpersonal relationships (Sourander et al., 2010). Several factors contribute to the occurrence of cyberbullying among children. These include individual characteristics, such as low self-esteem, social anxiety, and a lack of coping skills (Kowalski et al., 2014). Family dynamics, peer relationships, and school climate also play significant roles in influencing children's susceptibility to cyberbullying victimization (Smith et al., 2008). Additionally, the anonymity and perceived impunity afforded by online platforms can embolden perpetrators to engage in cyberbullying behaviors (Tokunaga, 2010).

While cyberbullying poses significant challenges to children's mental health, certain protective factors and coping strategies can mitigate its adverse effects. Strong parental support, positive peer relationships, and school-based interventions have been shown to buffer against the negative consequences of cyberbullying (Hinduja & Patchin, 2015). Teaching children resilience skills, fostering empathy and kindness, and promoting digital literacy and responsible online behavior are essential components of prevention and intervention efforts (Dooley et al., 2009). Parents, educators, policymakers, and mental health professionals must collaborate to develop effective interventions and preventive measures to mitigate its harmful effects, creating safe online environments and providing support to avoid cyberbullying. Previous studies suggested that raising cybersecurity awareness, promoting digital literacy, and fostering empathy and respect among children would help to combat cyberbullying and cultivate healthier online communities for future generations (Desimpelaere, Hudders, & Van de Sompel, 2020; Johnston, 2021; Quayyum, Cruzes, & Jaccheri, 2021).

The present study designs a quantitative survey interview to collect empirical data to examine the cyberbullying experiences of adolescent children in the U.S., the effects of cyberbullying experiences, their opinions of cyberbullying victimization, and protective factors to help them avoid cyberbullying. Three machine learning models, a Principal Component Analysis (PCA) model, a decision-tree model, and a K-Nearest Neighbors (KNN) model, are processed to describe the patterns in their cyberbullying experiences. The top variables that are closely related to cyberbullying victimization are identified. The deciding factors to define adolescent children's perception of cyberbullying victimization are also examined.

Data and Methods

Data for this study were from paper-based in-person survey interviews administered among adolescents aged 12 to 17 years residing in the Hampton Roads area in Virginia. Our survey questionnaire includes 48 closed-ended questions, asking about children’s socio-demographic background information, their digital engagement experiences, their experiences of cyberbullying and the consequences, their opinions of motivations for cyberbullying, and how to prevent cyberbullying. Our study subjects were randomly recruited from different neighbourhoods in the Hampton Roads area in Virginia, representing a wide variety of socio-economic settings in this area. We have followed the human study subject’s protection protocol in recruitment and interviewing, which has been approved by the Institutional Review Board at Norfolk State University. Both parental and child consent were obtained to participate in the study. All data are based on participating children’s self-reported answers to questions in the questionnaire. Our final data set includes 380 valid cases with information for all questions.

Participants

All adolescent children included in this analysis were residing in the Hampton Roads area of Virginia when they were interviewed. The average age of our study subjects was 14 years (Figure 1). Children from all racial groups were recruited (Figure 2). As presented in Figure 3, boys (58.16%) were slightly overrepresented than girls (41.84%), and the majority of participants (74.21%) were from two-parent households (Figure 4).

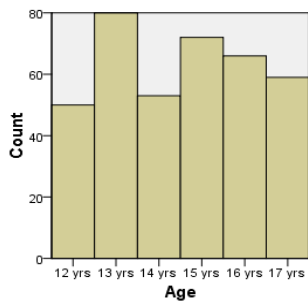


Figure 1. Distribution of Age (N = 380)

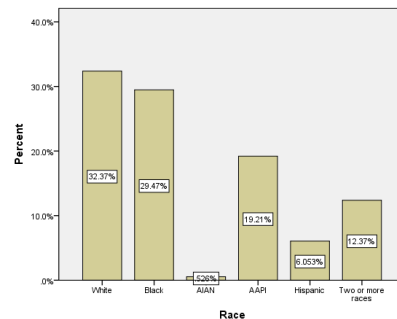


Figure 2. Distribution of Race/Ethnicity (N = 380)

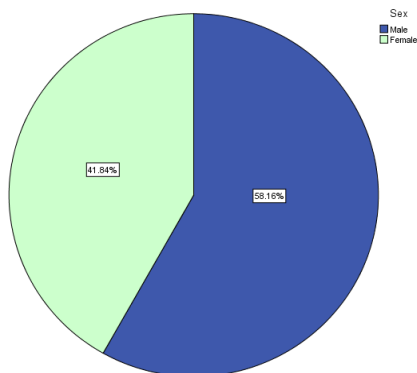


Figure 3. Distribution of Sex (N = 380)

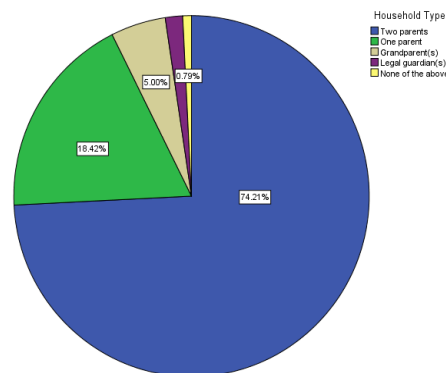


Figure 4. Distribution of Household Type (N = 380)

Measures

Cyberbullying Experiences. Participating children were asked how often they “have been made fun of in a chat room?” “Has someone sent or posted cruel gossip, rumors, or harmful material about you?” “Have you received a mean, threatening, or hurtful email?” “Has someone posted or sent material online that damaged your reputation?” “Has someone posted or sent material online that damaged your friendship?” “Has someone posted something online that made you sad, uncomfortable, or afraid?” “Has someone posted or shared your secrets or images online without your permission?” and “Have you engaged in an online argument or a fight?”

Cyberbullying Victimization. Children were asked whether they had been victims of cyberbullying.

Cybersecurity Talk at Home. Respondents were asked whether their family had discussed the risks and safety concerns associated with using the Internet and social media.

Cybersecurity Talk at School. Respondents were asked whether their school had taught them about the risks and safety concerns of using the Internet and social media.

Cyberbullying Talk at School. Respondents were asked whether their school had sessions or education to teach them about cyberbullying.

Perception of Online Interaction. Respondents were asked whether they thought online interactions were safer than in-person interactions.

Perception of Privacy Importance. Respondents were asked about their opinion of the importance of online privacy.

Clicking the link or downloading files from unknown sources. Respondents were asked whether they had clicked links or downloaded files from an email or message from someone they didn’t know personally.

Children’s Demographic Background Factors. Children’s demographic background information was also examined, including their sex (male vs. female), age (specific number of the year from 12 to 17), race/ethnicity (white, Black, AAPI, AIAN, Hispanic, two or more races), their household type (two-parent, one-parent, grandparent, legal guardian, or other), and their parents’ or guardians’ highest level of education completed.

Analytical Strategy

This study tried machine learning analysis with Python to identify the key patterns of cyberbullying victimization among adolescents, using data we have collected with survey interviews. Specifically, Principal Component Analysis (PCA) was applied to identify the key contributors to cyberbullying victimization. A decision-tree model was then used to predict adolescent children’s cyberbullying victimization. Finally, the K-Nearest Neighbor (KNN) Method was used to recognize the deciding factors of cyberbullying victimization.

Results

Principal Component Analysis for Cyberbullying Victimization

Principal Component Analysis (PCA) was applied to reduce the dimensionality of the survey dataset and identify underlying patterns across variables. Standardizing the numeric responses and transforming them into uncorrelated principal components, PCA captures the directions (components) that explain most variance in the data. In this study, our PAC

model focused on cyberbullying victimization (variable Q31 in our dataset) as a key factor in this analysis. Our analysis indicates that our dataset has 29 PC components in total. PC 15 with a loading of 0.474 will be the principal component that captures the most variance in cyberbullying victimization. The following Table 1 summarizes the top variables that are closely related to our cyberbullying victimization from the PCA analysis, including how often they use the Internet after school, whether they think online interaction is safer than in-person interaction, whether they have been made fun of in a chat room or other online communities, whether their school has had taught them about the risks online and in using social media, whether they have been engaged in online argument, whether they think privacy is important for online interaction, whether they have been excluded from an online group, whether they have clicked unknown links or have downloaded files sent by someone they do not know, and whether their school has taught students how to recognize cyberbullying and appropriate manners to respond cyberbullying.

Table 1. Top Variables Closely Related to Cyberbullying Victimization

Component/Variable	PCA Loadings
Frequent use of the Internet	0.3709901311306226
Online interaction safer	0.1882579165383395
Have been made fun of online	0.18579510326331014
Online risks talk at school	0.1832268660365737
Engaged in online arguments	0.14064764321258733
Perception of online privacy	0.13638772902074192
Have been excluded from an online group	0.08304987
Have clicked an unknown link	0.06760341
Cyberbullying education at school	0.02730062

*PCA Loadings: PCA loadings are the correlation coefficients between the original variables and the principal components (PCs). They show how much each original variable contributes to a specific principal component.

Table 1 indicates that the top five factors that are closely related to cyberbullying victimization are adolescent's frequency of using the Internet after school, their perception of online interaction safety in comparison to in-person interaction, their experiences of having been made fun of in a chat room or other online communities, whether their school has had taught them about the risks online and in using social media, whether they have been engaged in online argument.

Decision Tree Findings of Deciding Factors for Cyberbullying Victimization

The Decision Tree method was applied to identify the most influential factors predicting responses to cyberbullying victimization (variable Q31VICTIMCYB in our dataset). The model works by splitting the dataset recursively based on feature values to create branches that lead to the most homogeneous subgroups defining the target variable. Our decision-tree model analysis reveals that the following variables are key predictors of cyberbullying victimization, including the experience of witnessing cyberbullying (variable Q32WITNESSCYB in our dataset), someone has sent or posted online cruel gossip, rumours, or harmful material (variable Q30B_HMPOST in our dataset), have received mean, threatening, or hurtful emails (variable Q30C_HTEMAIL in our dataset), and having engaged themselves in an online argument or fight (variable Q30I_ONLARGUE in our dataset). These factors reflect direct or indirect exposure to hostile online behaviours. The decision tree provides both interpretability and a structured way to understand how

different forms of online interaction contribute to the likelihood of victimization, making it a powerful tool for educational and psychological analysis.

We use Gini Impurity to assess how “pure” a node is (i.e., how mixed the classes are). The range of Gini Impurity is from 0 to 0.5. The lower Gini Impurity implies the node contains mostly one class. In our decision tree model predicting cyberbullying victimization (variable **Q31VICTIMCYB**), the **three classes** come from the different response levels to the survey question about cyberbullying victimization. Based on the data and structure, three classes of the following **ordinal categories** are represented:

- **Class 1** → Low or No Victimization
- **Class 2** → Moderate Victimization
- **Class 3** → High Victimization

The Decision Tree output is presented below in Figure 5. The Decision-Tree model reveals a structured, interpretable model that identifies key predictors influencing a respondent’s experience with online harm. The tree splits primarily on items related to exposure to online risks, such as witnessing cyberbullying (Q32WITNESSCYB), exposure to harmful posts (Q30B_HMPOST), receiving hurtful emails (Q30C_HTEMAIL), and engaging in online arguments or fights (Q30I_ONLARGUE). These variables reflect the digital and emotional environment surrounding adolescents and how they relate to their perceived level of cyber victimization. The tree also incorporates whether they could get support from their teachers to handle cyberbullying appropriately (variable Q47TEACHKN in our dataset), which suggests the importance of resources and support in mitigating online risks.

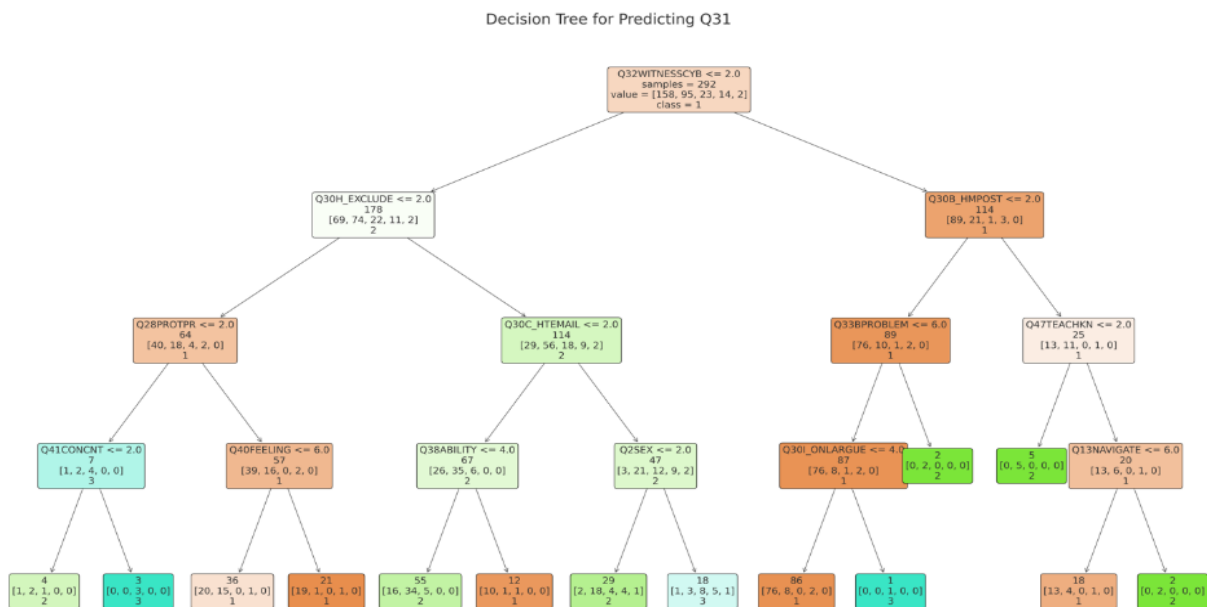


Figure 5. Decision-Tree Analysis of Predicting Levels of Cyberbullying Victimization

The decision tree constructed to predict responses to Q31 (Cyber Victimization) reveals a structured, interpretable model that identifies key predictors influencing a respondent’s experience with online harm. The tree splits primarily on items related to exposure to online risks, such as Q32WITNESSCYB (witnessing cyberbullying), Q30B_HMPOST (exposure to harmful posts), Q30C_HTEMAIL (receiving hurtful emails), and Q30I_ONLARGUE (online arguments). These variables reflect the digital and emotional environment surrounding the individual and how it relates to their perceived level of cyber victimization. The tree also incorporates social awareness

variables like Q47TEACHKN, which suggests the importance of support systems in mitigating online risks.

The decision tree method is a powerful tool for discovering interpretable patterns in the dataset. Its transparent structure allows educators, researchers, and policymakers to trace decision paths and understand how specific behaviors and exposures contribute to victimization. Most importantly, it highlights actionable predictors, suggesting that strengthening digital safety education and adult awareness could directly reduce negative online experiences among youth.

K-Nearest Neighbor Findings in Deciding Factors of Cyberbullying Victimization

We then applied the K-Nearest Neighbors (KNN) method to identify the key factors influencing responses to degrees of cyberbullying victimization feeling. KNN is a non-parametric classification algorithm that predicts the class of a sample based on the majority of its nearest neighbors in feature space. To infer which variables are most influential in predicting levels of cyberbullying victimization, we combined KNN with feature selection using ANOVA F-tests, which rank variables based on how well they discriminate between different levels of cyberbullying victimization feeling.

The following Table 2 summarizes the key findings from the KNN model, presenting the deciding factors to define cyberbullying victimization feelings among adolescents. The "Score" in the table comes from the ANOVA F-test (Analysis of Variance), which is used here to evaluate how strongly each feature (survey item) is associated with the target variable level of cyberbullying victimization feeling. It measures the ratio of between-group variance to within-group variance. A higher score indicates that the feature is more statistically significant in distinguishing between different levels of cyberbullying victimization feelings. KNN analysis results in Table 2 identify the top deciding factors that make adolescents get a stronger feeling of being victimized by cyberbullying, including the experiences of having received mean or hurtful emails; someone has posted or sent something online to damage their reputations; someone has posted something that made them feel sad, uncomfortable or fear; they have engaged in online arguments or fights; someone has posted or shared their personal information or image without their permission, and so on.

Table 2. KNN Analysis Results of Deciding Factors for Cyberbullying Victimization

Feature	Score
Have received mean or hurtful emails	29.62468658641834
Someone posted or sent something online to damage their reputation	25.19897219960894
Someone posted something online that made them sad or uncomfortable	18.191158265122404
Have engaged themselves in an online argument or fight	18.008982823802057
Someone posted or shared their personal information without permission	16.468482612024655
Someone posted something online that damaged their friendship	16.45128713675368
Have been a witness to someone being cyberbullied	16.28164408733327
Someone has sent or posted cruel gossip, rumors about them	15.322005424946129
Have been excluded from an online group	15.250968699757866
Have been made fun of in an online chat room	11.814581361674444

The KNN approach identified key predictors related to digital interaction experiences, including receiving mean, threatening, or hurtful emails; reputational damage caused by online posts; feelings of sadness, fear, or discomfort due to someone's online posting; and engagement in online arguments or conflicts.

These findings suggest that emotional impacts and direct online confronts are central to understanding victimization, and KNN effectively highlights these patterns by analyzing proximity-based behavior similarly across respondents. For example, responses to items such as **Q31VICTIMCYB** (which likely relates to experiences of cyber victimization) can be analyzed in the context of these components. If the cyberbullying victimization variable shows high loading on the first few principal components, especially alongside other mental health or cyber-related questions, it suggests that these items reflect a shared underlying construct, such as emotional impact or online behavior. These components allow us to interpret latent themes across the data, identify clusters of related responses, and potentially reduce noise for further modeling or classification.

Discussion & Conclusion

All three methods consistently pointed to emotional and social online experiences, such as being the subject of hurtful emails, online arguments, and harmful posts, as the most influential factors in predicting cyberbullying victimization (Q31VICTIMCYB). Each method offered a unique lens: PCA grouped these factors under a latent component, the decision tree revealed them as critical branching points, and KNN ranked them based on statistical separation.

The Decision Tree method is ideal when the goal is to identify specific decision rules and actionable variables influencing cyberbullying victimization. It offers a straightforward map from predictors to outcomes and is easy to explain to stakeholders like educators or parents. It maps out how different responses contribute to cyberbullying victimization classifications.

In contrast, PCA excels at uncovering underlying structures and themes in the data. It doesn't directly predict cyberbullying victimization, but it shows that cyberbullying victimization variable clusters with digital exposure and enjoyment items, suggesting deeper behavioral and lifestyle patterns that correlate with cyberbullying victimization. PCA is best for exploratory analysis, revealing broader behavioral patterns (e.g., cyberbullying victimization variable co-loading with online activity variables and emotional response features).

The KNN excels in detecting similarity-based patterns, especially where relationships may not follow simple rules. With ANOVA F-scores to rank features, KNN identified variables that significantly separate different levels of cyberbullying victimization, but it doesn't provide clear decision logic on its own. KNN is useful for identifying similarity-driven groupings in behavior, especially when paired with statistical tests like ANOVA to extract the most discriminative features.

The convergence across these models strengthens the reliability of the findings. Specifically, the consistently top-ranked variables (e.g., have received mean, threatening, or hurtful emails, have engaged in an online argument or fight, someone has posted something online that made them feel sad, uncomfortable, or afraid) highlight a core cluster of behaviors that not only reflect cyberbullying events but also emotional responses to those events. This suggests that intervention efforts should not just address cyberbullying incidents directly but also need to understand and support the emotional impact that accompanies them.

From a modeling perspective, PCA is valuable for exploratory analysis to understand structure, whereas a Decision Tree model is best for explainable prediction. However, the KNN model is ideal for capturing nonlinear group behaviors.

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