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СИТИ SCIENCE

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Mapping Technology-Facilitated Gender-Based Violence in Mongolian Secondary Schools: National Prevalence and Gender Differences

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***Abstract* - Technology-facilitated gender-based violence (TFGBV) has become a critical threat to youth well-being in digital environments, yet nationally representative evidence from Mongolia has been limited. This study examines the prevalence and gendered patterns of TFGBV among secondary school pupils using data from a nationwide cross-sectional survey (N = 17,908). Exposure was measured using 29 binary indicators capturing diverse forms of digital violence, including cyberbullying, hate speech, image-based abuse, impersonation, hacking, sextortion, and online grooming etc., Descriptive statistics were used to estimate prevalence, and chi-square tests assessed gender differences. Results indicate that TFGBV is highly prevalent, with the most common forms being hate speech (23.2%), cyberbullying (21.5%), defamation (20.9%), catfishing (19.9%), and cyberflashing (19.7%). Gender differences were statistically significant for 27 of the 29 indicators. Cyberbullying and hate speech showed no significant gender variation, whereas boys reported higher exposure to control and intrusion-oriented behaviors (e.g., hacking, denial of access, recruitment) as well as identity manipulation and sexualized coercion (e.g., impersonation, deepfakes, sextortion). Girls reported slightly higher exposure to cyberflashing. These findings demonstrate that TFGBV is widespread and structurally patterned by gender, underscoring the need for gender-responsive digital safety education, strengthened institutional responses, and targeted prevention strategies.**

Keywords* - *Technology-facilitated gender-based violence, gender differences, gender study, digital safety, Mongolia.

INTRODUCTION

The rapid digitalization of contemporary societies has fundamentally transformed how young people communicate, access information, and participate in social life. Over the past decade, the internet has become deeply embedded in the everyday routines of youths, shaping their education, entertainment, social interactions, and identity formation. In Mongolia, digital engagement among youth has risen sharply; within the last five years alone, the total number of internet users has increased by approximately 447,000. According to DataReportal (2025) [1], approximately 2,900,000 people in Mongolia were internet users, and internet penetration accounted for about 83% of the total population. As young people spend more time online, both the opportunities and the risks associated with digital participation have intensified.

Although the internet provides unprecedented avenues for learning and social connection, it has simultaneously created new environments where harassment, exploitation, discrimination, and violence can occur with ease, anonymity, and amplified impact. One of the most pressing emergent concerns is technology-facilitated gender-based violence (TFGBV) - a broad umbrella term referring to harmful acts that are committed, assisted, aggravated, or amplified through digital technologies such as social media platforms, messaging applications, and mobile devices [2], [3], [4]. These acts include cyberbullying, cyberstalking, gendered hate speech, image-based abuse, non-consensual sexual communication, online grooming, and coercive sexual extortion [5], [6].

Despite rapid global growth in TFGBV research, Mongolia lacks national-level empirical evidence, and digital forms of gender-based violence remain largely absent from public policy discourse. A recent multi-sector dialogue led by the National Human Rights Commission noted that TFGBV - especially cyberbullying and online harassment is increasing among both higher and general education students but remains poorly defined and insufficiently addressed in legal and regulatory frameworks [7]. Until the present study, no nationwide quantitative research had examined the prevalence, typologies of TFGBV among Mongolian youths.

To address this critical gap, the present study draws on one of the largest national adolescent datasets collected in

Mongolia (N = 18,044) to examine the prevalence of TFGBV among secondary school pupils.

Beyond its academic contribution, this study offers actionable evidence for improving digital safety education, teacher and staff training, school-based reporting mechanisms, and national policy development. Given that most Mongolian students prefer to disclose TFGBV experiences to family or peers rather than to school authorities [7], the findings underscore the urgent need to strengthen institutional capacity and trust.

In sum, this research provides the first comprehensive empirical portrait of TFGBV among Mongolian youths and positioned to inform both national policy and global TFGBV scholarship.

THEORITICAL FRAMEWORK

Digital technologies have profoundly reshaped interpersonal communication, creating new possibilities for interaction while simultaneously generating conditions for novel forms of violence, harassment, and discrimination [2], [4]. Within this evolving digital environment, Technology-Facilitated Gender-Based Violence (TFGBV) has emerged as a comprehensive framework for understanding harmful behaviors that are committed, assisted, aggravated, or amplified through digital tools including mobile devices, social media platforms, messaging applications, and advanced technologies such as artificial intelligence and deepfakes [5], [4]. Although earlier studies employed a range of overlapping terms-such as technology-facilitated abuse (TFA), technology-facilitated sexual violence (TFSV), and technology-facilitated gender and sexuality-based violence (TFGSV) to capture different dimensions of digital harm [2], [8], recent guidance from UN Women advocates for the unified use of the term TFGBV to enhance conceptual clarity and cross-study comparability [4].

This conceptualization highlights three core characteristics of TFGBV:

- First, digital mediation means that technology is not a passive conduit but an active agent that can facilitate, accelerate, and scale harmful behaviors.
- Second, gendered power dynamics underscore how structural inequalities, stereotypical norms, and intersectional hierarchies relating to gender and sexuality shape individuals' vulnerability to online harm [9], [8].
- Third, TFGBV is inherently multidimensional: digital acts produce enduring physical, psychological, social, and economic consequences, further blurring the boundaries between online and offline victimization [2], [3].

International scholarship generally categorizes TFGBV into four dominant typologies. International scholarship typically identifies four major TFGBV typologies:

(1) cyber sexual harassment (e.g., unsolicited sexual messages, pervasive sexualized harassment);

(2) image-based sexual abuse (IBSA) (e.g., non-consensual sharing of intimate images, deepfakes, digital voyeurism);

(3) technology-assisted sexual coercion and assault (e.g., sextortion, blackmail, coercive demands); and

(4) gender and sexuality-based harassment (e.g., hate speech, impersonation, doxing, outing) [5], [3].

Collectively, these typologies highlight that TFGBV operates along a continuum-from seemingly minor insults and degrading comments to severe violations with long-term consequences and that youths are increasingly exposed to multiple forms simultaneously [2], [8].

Digital platforms intensify the likelihood and severity of TFGBV due to several distinctive structural features. Anonymity and pseudonymity reduce accountability and embolden perpetrators [2]. Virality and permanence allow harmful content to circulate rapidly and persist indefinitely beyond the victim's control [6]. Networked digital environments enable coordinated harassment by multiple perpetrators or entire communities, amplifying the emotional and social impact [2]. Furthermore, constant connectivity eliminates traditional boundaries of time and space, meaning that violence can occur continuously without respite [10]. These dynamics make TFGBV uniquely invasive and difficult to escape.

Research from various regions indicates that youths are particularly vulnerable to TFGBV due to their high levels of digital engagement, developmental sensitivity, and peer-driven online cultures [3], [8]. Studies from Australia and Europe report high rates of cyber sexual harassment and IBSA among teenage girls, as well as considerable exposure to hate speech and cyber aggression among boys [5], [6]. Meta-analyses further demonstrate that technology-facilitated sexual violence is widespread, frequently normalized by peer groups, and strongly associated with emotional and behavioral problems [6]. Despite this, reporting rates remain low, especially among marginalized groups, due to limited digital literacy, stigma, and inadequate institutional support [9], [8].

TFGBV is consistently linked to a range of adverse psychological outcomes. Victims frequently experience fear, anxiety, anger, shame, self-blame, and social withdrawal [2], [3]. These emotional impacts extend to academic performance, relationships with peers and family, and overall health and well-being, with some victims developing long-term trauma symptoms [5], [6]. Scholars increasingly emphasize that the psychological effects of TFGBV can be equal to, or more severe than, those associated with offline gender-based violence, particularly given the persistence, uncontrollability, and public visibility of digital traces [6].

In response to TFGBV, youths tend to utilize two broad categories of coping strategies. Problem-focused coping involves actions intended to reduce or eliminate harm, such as reporting incidents, blocking perpetrators, documenting evidence, seeking help, and adjusting privacy settings [2], [9]. When supported by effective institutional mechanisms, these strategies can interrupt cycles of violence and reduce psychological distress. Avoidance coping, however, includes ignoring incidents, minimizing their seriousness, withdrawing from digital spaces, or deactivating accounts [11], [8]. Although avoidance may offer short-term emotional relief, research shows that it often exacerbates long-term distress because underlying threats remain unresolved [6]. Thus,

coping strategies play a mediating role in shaping the relationship between TFGBV exposure and psychological outcomes.

Gender differences further complicate the landscape of TFGBV. While girls are frequently recognized as primary victims of sexual harassment and IBSA [5], [2], recent evidence indicates that boys also experience high levels of digital victimization-particularly through coercive behaviors, hate speech, and cyber aggression [6], [8]. Boys may be less likely to disclose victimization due to social stigma and gender norms, resulting in hidden or underreported male victimization [2]. Findings from the present Mongolian dataset align with this emerging international evidence, revealing higher rates of TFGBV exposure among boys than girls across multiple categories [7]. This result is also consistent with the findings of a study conducted among a limited sample of university students titled "Technology-Facilitated Gender-Based Violence: Evidence from Gender Differences among Students" which reported similar patterns.

Schools play a central role in preventing and responding to TFGBV, as they are primary environments where youths socialize and where online and offline violence often intersect. However, evidence across countries indicates that institutional responses remain weak. Teachers often lack training and clear protocols for addressing TFGBV; reporting mechanisms are underutilized; and students tend to trust family and peers more than school authorities or law enforcement [2], [7]. Digital safety education is often fragmented and rarely integrated systematically into curricula [8]. These challenges are evident in Mongolia, where nearly half of surveyed students reported never receiving information about TFGBV from teachers or school staff [7].

In summary, the existing literature highlights major gaps that the current study seeks to address the absence of national-level TFGBV data among Mongolian youths.

By addressing this gap, the present study provides the first comprehensive statistical mapping of TFGBV among Mongolian secondary school pupils, conducts subgroup analyses by gender and grade level, and contributes empirical evidence to inform national digital safety policies and school-based interventions.

METHODOLOGY

This study employed a quantitative, cross-sectional research design to examine the prevalence and patterns of technology-facilitated gender-based violence (TFGBV) among secondary school pupils in Mongolia. The primary objective was to document the extent of TFGBV exposure and describe differences across gender and grade levels using descriptive statistical analysis.

The target population comprised students in Grades 6 through 12 enrolled in public secondary schools across Mongolia. A multi-stage, school-based sampling approach was used to ensure national representativeness. First, schools were selected from all nine districts of Ulaanbaatar and the twenty-one provinces. Second, all students in these schools were invited to participate via an online survey link distributed through official school communication channels. A total of 18,044 students responded to the survey, of whom 17,908 provided valid responses that were included in the analysis. Of these respondents, 6,350 were boys (35.5%) and 11,558 were girls (64.5%), ranging in age from 11 to 18 years. The sample reflected broad geographic, socioeconomic, and digital access diversity, supporting generalizability to the national population of Mongolian secondary school pupils [7].

Data collection took place between November 12 and December 24, 2025, through a secure online survey administered in collaboration with the National Human Rights Commission and City University of Mongolia. Students accessed the survey using mobile phones, tablets, or school computers. Prior to participation, all respondents were presented with an information sheet outlining the study's purpose, confidentiality protections, anonymity, voluntary participation, and the right to withdraw at any time. Informed consent was obtained electronically, and no personally identifiable information was collected. Ethical approval was granted by the City University of Mongolia, with formal endorsement from the National Human Rights Commission.

The survey measured TFGBV exposure using 29 binary (Yes/No) indicators capturing a wide range of digital violence behaviors, including hate speech, cyberbullying, cyber sexual harassment, image-based sexual abuse (e.g., upskirting, creepshots, digital voyeurism), impersonation, doxing, hacking, sexual coercion or sextortion, deepfake exploitation, technology restriction, and online grooming [2], [5], [3].

Data analysis was conducted using SPSS version 29.0. Procedures included data cleaning, coding, and the computation of descriptive statistics (frequencies, percentages, and cross-tabulations). TFGBV prevalence rates were calculated for each indicator and summarized by gender and grade level. Group differences were examined using cross-tabulated distributions to illustrate patterns of exposure across demographic categories. These analyses provided baseline insights into TFGBV exposure among Mongolian secondary school pupils and enabled the identification of high-risk groups for future in-depth analytical studies [7].

Sample characteristics

A total of 17,908 secondary school pupils provided valid responses to the demographic section of the survey. The gender distribution showed that 35.5% were boys (n = 6,350) and 64.5% were girls (n = 11,558). Participants' ages ranged from 11 to 18 years (M = 14.12), with the largest age groups being 13-15-year-olds, who collectively comprised more than 48% of the sample.

Regarding household composition, the majority of respondents (68.6%) lived with both parents, while 13.1% lived only with their mother, 2.4% with their father, and the remainder lived with grandparents (5.9%) or other caregivers (10.1%).

Students were also asked whom they typically turned to when experiencing problems. More than half (54%) reported relying on family members, followed by friends (29.3%). Only a small proportion indicated they would seek help from teachers (2.2%), social workers (2.2%), or law enforcement agencies (2.2%), highlighting limited trust in formal institutional support structures. Notably, only 1.7% reported contacting the national child protection hotline (108), and 3.0% said they would seek help from a psychologist.

Participants identified the digital platforms where they most commonly encountered online harassment or

technology-facilitated abuse. More than half (54.6%) reported Facebook as the primary venue, followed by NGL (4.8%), Instagram (3.1%), Telegram (1.3%), and Roblox (1.2%). A sizeable minority (25.7%) indicated no specific platform. The category "Other platforms" accounted for 7.4%, suggesting a wide variety of emerging digital spaces where violence may occur.

Students represented grades 6 through 12, with relatively even distribution across grade levels: Grade 6 (13.0%), Grade 7 (12.8%), Grade 8 (14.7%), Grade 9 (15.2%), Grade 10 (16.1%), Grade 11 (13.8%), and Grade 12 (14.3%).

Daily digital engagement was high. Only 8.4% spent less than 30 minutes online per day, whereas the majority spent 2-3+ hours online (52.9%), and almost 24% reported spending 4 or more hours per day on digital devices or social media. Most students had 3-5 years of internet experience (58.2%), with 21.5% reporting four years and 19.4% reporting three years of use.

When asked who typically perpetrated online harassment or violence against them, 30.1% identified strangers on social media, 9.8% pointed to friends, 7.9% to classmates, and 9.4% to online gaming partners. A substantial proportion (41.8%) selected "Other," suggesting varied or unidentifiable sources of online harm.

Participants were drawn from all districts of Ulaanbaatar and all 21 provinces, indicating wide national coverage. The largest representations came from Dornod (12.9%), Khan-Uul district (13.1%), and Darkhan-Uul (9.7%), ensuring adequate regional diversity.

Finally, students were asked whether their schools or teachers had provided any information on TFGBV or digital safety. Responses were almost evenly divided: 50.7% reported receiving such information, while 49.3% had not, indicating inconsistency in digital safety education across schools.

RESULTS

Descriptive analysis presented in Table 1 revealed that multiple forms of technology-facilitated gender-based violence (TFGBV) were widespread among Mongolian secondary school pupils. The most prevalent form was hate speech (23.2%), followed by cyberbullying (21.5%), defamation (20.9%), catfishing (19.9%), cyberflashing (19.7%), and flaming (19.0%).

Moderately prevalent forms included deadnaming (18.6%), cyberstalking (17.6%), hacking (17.3%), impersonation (17.3%), trolling (16.8%), cyberobsessional pursuit (16.7%), and doxing (16.5%). Exposure to deepfake-based synthetic sexual media (15.7%), denial of access (15.6%), online harassment (15.1%), limiting or controlling use of technology (14.5%), and image-based abuse (14.4%) was also reported by a substantial proportion of respondents.

Less frequently reported forms of TFGBV included online grooming (13.4%), electronically enabled financial abuse (13.3%), recruitment (12.8%), revenge porn (11.7%), sexting and abusive sexting (11.6%), shock and grief trolling (10.9%), slut-shaming online (10.9%), sextortion (10.7%), and upskirting, creepshots, and digital voyeurism (10.6%).

TABLE I. PREVALENCE OF TFGBV BY TYPE (RANKED, %)

Rank	TFGBV type (English)	Монгол нэршил	%
1	Hate speech	Үзэн ядсан үг хэллэг	23.2
2	Cyberbullying	Цахим дээрэлхэл	21.5
3	Defamation	Гүтгэлэг, нэр төрд халдах	20.9
4	Catfishing	Хуурмаг дүр эсгэх	19.9
5	Cyberflashing	Садар самуун зураг, бичлэг илгээх	19.7
6	Flaming	Санаатай доромжлох, гутаах	19
7	Deadnaming	Нэрийг нь зөвшөөрөлгүй илчлэх	18.6
8	Cyberstalking	Цахим орчинд мөшгих	17.6
9	Hacking	Хууль бусаар нэвтрэх	17.3
10	Impersonation	Өөр хүний дүрд хувирах	17.3
11	Trolling	Өдөөн хатгах, доромжлох	16.8
12	Cyberobsessional pursuit	Цахимаар хөөж мөшгиж дарамтлах	16.7
13	Doxing	Хувийн мэдээллийг нийтэд тараах	16.5
14	Deepfakes (synthetic sexual media)	Хиймэл дүрс бичлэг	15.7
15	Denial of access	Мэдээллийн хүртээмжийг хязгаарлах	15.6
16	Online harassment	Онлайнаар дарамтлах	15.1
17	Limiting/controlling use of technology	Цахим хэрэглээг хянах, хязгаарлах	14.5
18	Image-based abuse	Зурагт суурилсан хүчирхийлэл	14.4
19	Zoom-bombing	Цахимаар халдах, мэдээлэл цацах	13.8
20	Retaliations against supporters of survivors	Хохирогчийг дэмжигчдэд заналхийлэх	13.8
21	Online grooming	Хүүхэдтэй бэлгийн агуулгаар холбоо тогтоох	13.4
22	Electronically enabled financial abuse	Цахим санхүүгийн дарамт	13.3
23	Recruitment	Урхидан элсүүлэх	12.8
24	Revenge porn	Садар самуун зураг, бичлэг тарааж дарамтлах	11.7
25	Sexting & abusive sexting	Садар самуун зурвас, зураг илгээх, дарамтлах	11.6
26	Shock and grief trolling	Нас барсан хүний мэдээллээр доромжлох	10.9
27	Slut-shaming online	Садар самуунтай холбон доромжлох	10.9
28	Sextortion	Бэлгийн шинжтэй сүрдүүлэг	10.7
29	Upskirting, creepshots & digital voyeurism	Нууцаар зураг авах, бичлэг хийх	10.6

While UNFPA (2024) reports that 38% of women with internet access experience technology-facilitated gender-based violence, global evidence suggests that approximately 25-35% of men also report exposure to online abuse or harassment, although prevalence rates are generally lower than those observed among women [12], [10].

Chi-square tests of independence were conducted to examine gender differences across 29 indicators of

technology-facilitated gender-based violence (TFGV) (N = 17,908). Significant gender differences were observed for 27 of the 29 indicators (see Table 2). Only cyberbullying and hate speech did not show statistically significant gender variation, indicating comparable exposure among men and women for these two forms.

Across the remaining indicators, gender differences were evident for a broad range of TFGV manifestations, including pursuit and deception-related behaviors (e.g., cyberobsessional pursuit, catfishing, cyberstalking, and deadnaming) as well as identity manipulation practices such as deepfakes, impersonation, and doxing. Control and intrusion-oriented forms of abuse (e.g., hacking, denial of access, limiting or controlling technology use, financially enabled abuse, and recruitment) exhibited particularly consistent gender differentiation.

Sexualized and coercive forms of TFGV, including revenge porn, sexting and abusive sexting, sextortion, slut-shaming, digital voyeurism, and shock-and-grief trolling, also showed significant gender variation. Although most associations reached statistical significance, effect sizes were uniformly small, indicating modest but systematic gender differences across multiple forms of technology-facilitated violence.

Taken together, these findings indicate that while highly visible forms of online hostility such as cyberbullying and hate speech affect men and women at similar levels, the majority of TFGV indicators are structurally differentiated by gender, particularly for forms involving technological intrusion, identity manipulation, and sexualized coercion.

TABLE II. TABGENDER DIFFERENCES IN TECHNOLOGY-FACILITATED GENDER-BASED VIOLENCE (N = 17,908)

Indicator	Men (%)	Women (%)	χ^2	df	p	Cramer's V
Cyberbullying	21.1	21.7	0.95	1	.331	.007
Cyberobsessional pursuit	18.2	15.9	15.07	1	< .001	.029
Catfishing	23.5	17.9	81.31	1	< .001	.067
Cyberflashing	18.6	20.3	7.63	1	.006	.021
Cyberstalking	18.7	17.0	7.86	1	.005	.021
Deadnaming	20.4	17.5	21.75	1	< .001	.035
Deepfakes	18.3	14.4	46.75	1	< .001	.051
Defamation	21.9	20.4	5.85	1	.016	.018
Denial of access	18.2	14.2	50.07	1	< .001	.053
Doxing	18.2	15.6	20.63	1	< .001	.034
Financial abuse	16.8	11.3	106.29	1	< .001	.077
Flaming	19.8	18.5	4.60	1	.032	.016
Hacking	21.3	15.1	110.73	1	< .001	.079
Image-based abuse	16.6	13.2	38.87	1	< .001	.047
Hate speech	22.7	23.5	1.35	1	.245	.009
Impersonation	19.2	16.3	24.11	1	< .001	.037
Limiting tech use	17.1	13.1	52.86	1	< .001	.054
Online grooming	14.4	12.8	9.28	1	.002	.023
Online harassment	17.1	14.1	28.72	1	< .001	.040
Recruitment	16.0	11.0	91.74	1	< .001	.072
Retaliations	16.4	12.3	57.02	1	< .001	.056
Revenge porn	14.5	10.1	75.91	1	< .001	.065
Sexting/abusive sexting	14.0	10.4	51.30	1	< .001	.054
Sextortion	12.8	9.6	44.18	1	< .001	.050
Shock & grief trolling	13.4	9.4	68.38	1	< .001	.062
Slut-shaming online	13.4	9.6	61.23	1	< .001	.058
Digital voyeurism	12.6	9.5	42.95	1	< .001	.049
Trolling	19.4	15.3	50.40	1	< .001	.053
Zoom-bombing	15.4	13.0	20.86	1	< .001	.034

[a.] Note. Percentages represent prevalence within gender. χ^2 = Pearson chi-square statistic. df = degrees of freedom. V = Cramer's V.

DISCUSSION

The present study provides the first nationally representative quantitative evidence on the prevalence and gendered patterns of technology-facilitated gender-based violence (TFGBV) among secondary school pupils in Mongolia. The findings demonstrate that TFGBV is not a marginal phenomenon but a widespread aspect of young people's digital lives, with substantial proportions of students reporting exposure across all 29 measured indicators.

Consistent with international research [2], [3], [4], the most prevalent forms of TFGBV in Mongolia were hate speech, cyberbullying, defamation, and deceptive practices such as catfishing. These highly visible forms of digital hostility appear to constitute the dominant layer of online victimization, reflecting everyday peer interactions and normalized aggressive communication styles in digital spaces. At the same time, a considerable proportion of students reported exposure to more covert and invasive behaviors, including hacking, impersonation, doxing, deepfake exploitation, and image-based abuse, indicating that Mongolian youths face a broad continuum of digital harms rather than isolated incidents.

The chi-square analyses further revealed that gender plays a statistically significant role in shaping TFGBV exposure across the majority of indicators. While cyberbullying and hate speech were experienced at similar levels by boys and girls, most other forms showed systematic gender differentiation. Boys reported higher exposure to control- and intrusion-oriented behaviors (e.g., hacking, denial of access, financially enabled abuse, recruitment) as well as identity manipulation and coercive practices (e.g., impersonation, deepfakes, sextortion). This pattern aligns with emerging international evidence suggesting that male victimization in digital contexts may be more strongly associated with technical intrusion and coercive control [6], [8].

By contrast, girls exhibited slightly higher exposure to cyberflashing and comparable or marginally higher levels of cyberbullying and hate speech, suggesting that female victimization remains more concentrated in direct verbal harassment and unwanted sexualized content. These findings challenge simplistic assumptions that TFGBV is exclusively or primarily a female victimization phenomenon and instead support a more differentiated, gender-responsive understanding of digital violence.

Importantly, although effect sizes were small, the consistency of gender differences across a large national sample indicates that these disparities are not random but structurally patterned. TFGBV among Mongolian youths therefore appears to operate along two intersecting axes: highly visible hostility that affects both genders similarly, and technologically mediated coercion and manipulation that disproportionately affects boys in this sample.

A. Policy and Practice Implications

The findings have important implications for digital safety policy and school-based interventions in Mongolia. First, the high prevalence of TFGBV across diverse forms underscores the need for comprehensive digital citizenship and safety education that goes beyond cyberbullying to address deception, image-based abuse, sextortion, and technologically enabled coercion. Current educational efforts appear fragmented, as nearly half of students reported never receiving information about TFGBV from school staff.

Second, the observed gender differentiation suggests that prevention strategies should be gender-responsive rather than gender-neutral. Programs aimed at girls should focus on protection from verbal harassment and unwanted sexual content, while interventions targeting boys should address risks related to hacking, coercion, and identity manipulation. Teacher training and school protocols must therefore incorporate a nuanced understanding of TFGBV typologies rather than relying on a narrow focus on cyberbullying alone.

Third, the low reliance on formal reporting channels highlights the need to strengthen trust in institutional responses. Clear reporting mechanisms, confidential support services, and integration with child protection and mental health systems are essential for reducing underreporting and mitigating long-term harm.

B. Limitations and Future Research

Several limitations should be acknowledged. First, the study relies on self-reported data, which may be affected by recall bias or social desirability, particularly for sensitive behaviors. Second, the cross-sectional design does not allow for causal inference regarding the relationship between TFGBV exposure and psychological or educational outcomes. Third, although the survey captured a wide range of behaviors, it did not measure severity, duration, or perpetrator motivations, which may shape the impact of victimization.

Future research should employ longitudinal designs to examine the developmental consequences of TFGBV and explore how coping strategies and institutional responses mediate its effects. Qualitative studies could also provide deeper insight into how youths interpret and experience different forms of digital violence. Comparative studies across countries in Central and East Asia would further strengthen the global relevance of Mongolian evidence.

CONCLUSION

This study provides the first comprehensive national portrait of technology-facilitated gender-based violence among secondary school pupils in Mongolia. The results demonstrate that TFGBV is widespread, multifaceted, and systematically patterned by gender. While highly visible forms such as cyberbullying and hate speech affect boys and girls at similar levels, most other forms of digital violence exhibit significant gender differentiation, particularly those involving technological intrusion, identity manipulation, and sexualized coercion.

By documenting the prevalence and structure of TFGBV in a large adolescent population, this research contributes critical empirical evidence to both national policy debates and international TFGBV scholarship. The findings underscore the urgency of integrating digital safety into education systems, strengthening institutional responses, and adopting gender-responsive prevention strategies. Without such measures, digital spaces risk becoming normalized environments of harassment and coercion for Mongolian youths rather than platforms for empowerment and participation.

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SQUARE AND CIRCLE: A STUDY ON GRAPHIC DESIGN IN MONGOLIAN TRADITIONAL PATTERNS

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***Abstract*—on the core motifs of "Square and Circle" within the Mongolian traditional pattern system, delving into the philosophical connotations of the cosmology of "round heaven and square earth" and their diverse artistic expressions behind them. Through a systematic review and critical examination of relevant domestic and international studies, this paper comprehensively analyzes the cultural symbolism, aesthetic concepts carried by these two geometric motifs, and their specific applications in historical artifacts, architecture, and ornaments. The study innovatively adopts a mixed methodology combining visual form analysis, semiotic deconstruction, and geometric quantitative models to decode their compositional principles, proportional relationships, and dynamic generative logic. The findings reveal that these motifs are not only crucial carriers for maintaining national visual identity but also embody inherent design wisdom characterized by high rationality and adaptability, demonstrating significant transformative potential for design innovation in contemporary fields such as brand identity, digital interfaces, and product styling. From a theoretical perspective of design studies, this research deepens the understanding of ethnic aesthetic systems and provides methodological references and practical pathways for the modern translation and innovative application of traditional visual culture.**

Keywords—Graphic Design; Cultural Heritage; Aesthetic Philosophy; Visual Analysis; Cultural Space Regeneration

I. INTRODUCTION

Mongolian traditional pattern art, as a typical representation of nomadic culture, profoundly embodies the aesthetic system and philosophical wisdom formed by the Mongolian people through their long-term practices in production and daily life. Among its numerous motifs, "the square and the circle" not only constitute fundamental visual forms but also resonate with the cosmological concept of "round heaven and square earth," carrying deep symbolic meanings of order, harmony, and the natural cycle. These patterns are not merely decorative elements but a cultural language that integrates symbolic semantics and spatial expression, systematically reflecting the Mongolian people's holistic understanding of the world, society, and beauty.

Although existing research has systematically examined Mongolian traditional patterns from perspectives such as art history, ethnology, and cultural studies, in-depth exploration from the perspective of modern graphic design theory — focusing on their formal structure, visual grammar, symbolic signification, and compositional logic—remains insufficient. Based on graphic design theory, this study systematically analyzes the visual organizational mechanisms, cultural symbolic functions, and transformative potential of the "square and circle" motif in Mongolian traditional patterns within modern design contexts. This aims to address the current gap in interdisciplinary research and provide theoretical support and practical references for the appropriate application of traditional patterns in contemporary cultural innovation and spatial regeneration.

This paper aims to place the "square and circle" motif, a core element of Mongolian traditional patterns, within the framework of modern graphic design theory for systematic analysis, revealing its inherent visual organizational mechanisms and design wisdom. By doing so, it seeks to compensate for the insufficient shift in existing research from art history and ethnology to the discipline of graphic design.

First, a sample system will be collected and organized. High-resolution images of traditional Mongolian artifacts (such as yurts, robes, saddles, bows and arrows, milk buckets, etc.) featuring the "square and circle" motif will be systematically gathered from published pattern compilations and authorized field investigation archives to establish a research sample database.

Next, a multi-dimensional analysis will be conducted. Visual form analysis: Qualitative analysis of the samples will be performed using core principles of graphic design, such as composition, figure-ground relationships, visual weight, and rhythm. Comprehensive interpretation and theoretical construction: The results of the above analyses will be synthesized to explain how "the square and the circle" function as a "visual language" and to derive its universal design principles.

Finally, application exploration and future prospects will be discussed. Strategies for transforming these patterns in contemporary design practices will be explored, and specific recommendations will be proposed for cultural heritage education, design tool development, interdisciplinary collaboration, and future academic research.

II. RESEARCH STATUS

Domestic research has provided extensive studies on the origins, symbolic meanings, and morphology of traditional

Mongolian patterns. In contrast, international research emphasizes comparative cultural perspectives, exploring the relationship between Mongolian and East Asian visual systems. Furthermore, scholars from Mongolia have conducted in-depth and scientifically grounded research on the pattern system.

A. Domestic Research Status

In recent years, domestic research on the graphic design of the "square and circle" in traditional Mongolian patterns has yielded fruitful results, covering various aspects including fundamental research, thematic studies, cultural interpretation, analysis of artistic characteristics, exploration of inheritance and development, as well as modern design applications.

At the level of fundamental research, numerous scholars have laid a solid foundation for the study of the "square and circle" graphics. Works such as Mongolian Traditional Art: Patterns by Amur Bator and Miao Rui, based on extensive fieldwork, systematically compile Mongolian patterns, providing abundant material for research. Similarly, Ulzii's Traditional Folk Patterns of the Mongolian Ethnic Group details the origins, classification, cultural symbolism, and drawing techniques of traditional patterns, establishing a basis for in-depth study.

Other literature analyzes the characteristics of traditional Mongolian patterns in terms of form, color, and composition, and discusses their origins, development, symbolic meanings, and aesthetic connotations [1].

Some studies interpret the "square and circle" graphics from a cultural perspective. Research like Li Jie's The Natural Ecological View in Mongolian Patterns and similar works posit that Mongolian patterns reflect the nomadic people's ideology of revering nature and focusing on essence. Within this framework, the "square and circle" graphics embody the Mongolian people's understanding of cosmic harmony and natural cycles.

Other research places the "square and circle" graphics within a broader cultural context [2]. Scholars analyze the relationship between nomadic culture and the agrarian culture of the Central Plains, providing historical background for the study of these graphics. For example, Liang Huiying's A Preliminary Comparative Study on the Evolution of Mongolian Folk Patterns and Central Plains Traditional Patterns explores the influence of multicultural factors on Mongolian patterns, offering a theoretical basis for summarizing the cultural characteristics of the "square and circle" graphics [3].

From a cultural viewpoint, the "square and circle" graphics reflect the unique worldview and values of the Mongolian people. The "square" symbolizes the steadfast and resolute character of the Mongols, while the "circle" reflects their understanding of cosmic harmony and related concepts. The patterns of the yurt (Mongolian ger) are closely linked to religious beliefs, and the design philosophy of "square and circle" is deeply rooted in its interior decoration, often combined with other patterns to create unique effects.

Research on artistic characteristics indicates that the "square and circle" graphics possess both aesthetic sensibility and ingenious wisdom. Their application in traditional architecture and other patterns is closely related to nomadic life. However, changes over time pose challenges to the inheritance of traditional Mongolian patterns. Regarding the preservation of yurt decoration, scholars have proposed suggestions such as strengthening education.

Domestic research has also explored the application of "square and circle" graphics in modern design, providing insights for the innovative inheritance of traditional culture, thereby revitalizing it.

B. International Research Status

International research on Mongolian culture is relatively limited, although some scholars focus on the design of "square and circle" patterns in traditional Mongolian art. Researchers of Eastern cultures have conducted comparative studies from cross-cultural perspectives, contrasting Mongolian "square and circle" patterns with similar motifs in other Asian ethnic groups. The work of Japanese scholar Kazuo Shiro, Comparison of Patterns Between East and West, provides theoretical reference, making it possible to explore philosophical similarities between Mongolian "square and circle" graphics and Japanese traditional patterns. These similarities reflect a shared understanding of natural harmony and expressions of cosmic and natural perception. Although manifestations may differ, their commonalities remain significant.

Lujin (2022) and Tsogt (2019) conducted comprehensive analyses of the origins, classification, and symbolic systems of Mongolian patterns, interpreting the square and circle motifs as embodiments of the unity of nature, humanity, and the cosmos [4].

Their works emphasize the philosophical and cultural significance of the ornamentation. In contrast, Gantuya, Bagabold, and Munkhzul (2025) introduced a new methodology by applying mathematical modeling and vector graphics to reinterpret traditional motifs, thereby linking traditional art with modern design technology [5].

Research by Enkhbat (2022) and Lavadiv (2021) examined the application of traditional ornamentation in Mongolian architecture and clothing design, highlighting their compositional logic and stylistic consistency. These works lay the groundwork for integrating traditional visual elements into contemporary design practice [6].

Key contributions by Mongolian scholars provide a solid scientific basis for pattern research. Л.Батчулуун (L. Batchuluun) (2018), in his seminal work Монголын уламжлалт хээ угалз (Mongolian Traditional Patterns), systematically classified patterns based on geometric origins and symbolic depth, providing a rigorous framework for formal analysis. Д.Энхдавaа (D.Enkhdavaa) (2019) applied a structuralist approach to decode syntactic relationships in pattern composition, revealing underlying organizational principles. Д.Цэдэн-Иш (D.Tseden-Ish) (2020) further advanced the field by integrating visual cognition theories to explain how traditional patterns are perceived and processed, thereby linking form with psychological impact. The doctoral dissertations of Р.Гоцбаяр (R.Gotsbayar) (2021, National University of Mongolia) on the semiotics of nomadic ornamentation and Б.Энхбат (B. Enkhbat) (2022, Mongolian University of Science and Technology) on the

algorithmic generation of traditional motifs are particularly relevant, as they directly address the intersection of traditional forms and contemporary design theory [7], [8].

Regarding graphic research literature, “Circle and Square”, edited by Yukimasa Matsuda with commentary by Shutaro Mukai and translated by Huang Bijun, compiles talismans, font designs, cosmological images, symbols, and visual poetry derived from circles and squares. From the visual perspective of graphic patterns, the book elucidates the aesthetic beauty of circles and squares, providing valuable insights for studying the "square and circle" graphic design in Mongolian culture.

Concerning the evolution and composition of patterns, The Composition of Mongolian Folk Patterns by the Mongolian scholar Idamzhav (1992) explains the initial forms and evolution of Mongolian patterns, offering a relatively objective interpretation of the "motif" significance of various patterns. This aids in a deeper understanding of the origins and development of "square and circle" graphic design in Mongolian culture. In 1994, Danish scholar Martha Buehl authored the monograph Mongolian Ornamentation, investigating the deep imagery, formal logic, and evolutionary patterns of decoration and decorative motifs, including "square and circle" graphic design. In 1998, British scholar Christina Chaperon, in her article The Relationship Between Mongolian Decorative Art and Various Aspects of Traditional Mongolian Culture, revealed the starting points, directions, and goals of Mongolian pattern evolution, identifying influences from different ethnic cultures on Mongolian motifs. This provides a basis for studying the cultural fusion behind Mongolian "square and circle" graphic design [9].

Furthermore, some international designers draw inspiration from Mongolian "square and circle" graphic design elements in their creations. By integrating these uniquely ethnic patterns into modern design works, they demonstrate cross-cultural exchange and fusion. These practices not only enrich the expressive forms of modern design but also play a positive role in promoting and disseminating traditional Mongolian patterns. For instance, in the field of fashion design, certain international brands incorporate Mongolian "square and circle" elements into pattern design and cutting styles, creating clothing that blends modern fashion with unique Mongolian cultural charm. These designs have garnered widespread attention and appreciation from consumers.

Although substantial research discusses the symbolic meanings and historical development of Mongolian ornamentation, few studies analyze it through graphic design principles such as visual hierarchy, balance, contrast, rhythm, and modular grid systems.

Furthermore, systematic analysis of the semiotic and geometric relationship between squares and circles within the composition of Mongolian patterns from a design perspective has not been undertaken.

The proposed topic, "Square and Circle: A Study of Graphic Design in Traditional Mongolian Patterns," aims to fill these gaps. It explores how traditional forms can be translated into the language of modern graphic design by:

Investigating visual geometry and structure,

Providing semantic interpretation of forms and symbols, and Developing visual systems applicable to branding, cultural identity, and digital design.

This direction supports the growing field of culture and heritage-inspired design, linking traditional Mongolian aesthetics with contemporary visual communication.

III. Research Methodology

Given the interdisciplinary nature of this study, which aims to decode traditional motifs through a modern design lens, a mixed-methods research approach was adopted. This approach combines qualitative visual and semiotic analysis with quantitative geometric measurements, ensuring both depth in cultural interpretation and objectivity in formal analysis.

This study employs an exploratory sequential mixed-methods design. The primary qualitative phase involves in-depth visual and semiotic analysis to understand the cultural and aesthetic dimensions of the patterns. The subsequent quantitative phase involves measuring geometric features to identify objective formal characteristics and patterns. High-resolution images of Mongolian traditional artifacts (e.g., Mongolian gers, clothing, saddles, utensils) were collected from published pattern compendiums and authorized fieldwork photographs. Each image was analyzed using core graphic design principles. This includes examining compositional layout, figure-ground relationships, visual weight distribution, and the use of lines/shapes to create rhythm and dynamism. Motifs were analyzed as signs. The signifier objects (cultural referents, e.g., land, sky) and the signified concepts (conceptual meanings, e.g., stability, eternity) were identified to map the signification processes.

IV. TRADITIONAL CHARACTERISTICS OF 'SQUARE AND CIRCLE'

The square symbolizes order, rationality, and structure, while the circle embodies harmony, inclusiveness, and the cyclical nature of life. The fusion of these two elements demonstrates the Mongolian philosophical concept of the unity of heaven and earth.

A. Embodiment of Philosophical Concepts

A The "square and circle" patterns in traditional Mongolian design are influenced by philosophical ideas. The "square" embodies stability and structural order, reflecting the Mongolian people's respect for norms and standards. In Mongolian social life, systems such as tribal organization exemplify the characteristics of the "square," ensuring social stability and promoting orderly development. The symbolism of the "circle" showcases the Mongolian reverence for infinite cycles and inclusivity, highlighting their profound awe for the cosmos and nature. They view the universe as a cyclical unity, a concept vividly captured in the "circle" pattern, where all things undergo constant evolution and proliferation. The notion of the universe's eternal cycle is vividly embodied in the "circular" pattern, symbolizing the perpetual transformation and multiplication of all things. Circular patterns in traditional Mongolian design represent celestial bodies, signifying the eternity of life and its cyclical nature.

B. Fusion of Aesthetic Ideals

The "square and circle" graphics in traditional Mongolian patterns reflect aesthetic ideals with distinctive features. The square embodies a robust and majestic beauty, as it conveys a sense of integrity and stability. The circle, with its soft and flowing qualities, communicates a beauty of harmony, highlighting the unique charm of the "circular" form. The Mongolian people integrate these two aesthetic qualities to create a unique aesthetic effect that balances strength with softness, and movement with stillness. In pattern design, the combination of "square and circle" can establish visual hierarchy, thereby generating diverse rhythmic sensations. Through the embedding of elements or the use of borders, patterns become more dynamic. Incorporating circular elements into square patterns can introduce variation, while surrounding circular patterns with square borders can make the design more engaging.

C. Symbolic Significance of Cultural Signs

In Mongolian culture, the "square and circle" graphics carry rich symbolic meanings, which not only reflect ethnic characteristics but also demonstrate profound cultural heritage. The "square" symbolizes the Mongolian people's emotional attachment to their homeland, often associated with land and home, expressing their love and protective feelings towards their native soil. Traditional Mongolian architecture showcases their pursuit of life, where the layout of square structures conveys a sense of stability, representing people's yearning for a settled life. The "circle" is associated with the sky and deities, reflecting the Mongolian reverence for the divine and their aspirations for a better life. Traditional Mongolian rituals demonstrate respect for deities, often employing circular offerings and utensils, symbolizing devout reverence for the divine.

V. Analysis and Findings: Manifestations in Traditional Mongolian Patterns

The 'square and circle' motif is extensively applied in Mongolian gers, clothing, and utensils. This section presents our findings from visual, semiotic, and geometric analyses, moving beyond cultural interpretation to elucidate their graphic design logic.

TABLE I. Design Functions of 'Square and Circle' Motifs in Mongolian Artifacts

Artifact Category	*Primary Function of Square*	*Primary Function of Circle*	*Key Design Principle Demonstrated*
Architecture (Yurt)	Spatial definition, structural framing	Unifying focus, centralizing vision	Contrast & Balance, Visual Hierarchy
Clothing (Robe)	Edge reinforcement, rhythmic border	Symbolic focal point, modular repetition	Alignment & Repetition, Figure-Ground
Utensils (Saddle)	Structural grid, directional guide	Centering element, radial symmetry	Proportion, Radial Balance

Overall Structure

The design of the Mongolian yurt skillfully integrates the "square" and "circle," showcasing the wisdom of the Mongolian people in adapting to their environment and highlighting their unique ability to thrive in the grassland ecosystem. The circular body of the yurt resembles a vast dome, standing firmly on the prairie. This circular design is the result of long-standing experience in harmonizing with nature, offering excellent stability and remarkable wind resistance. The grassland climate is unpredictable, with strong winds frequently occurring. The circular shape of the yurt evenly disperses wind force, allowing it to glide smoothly along the curved surface and preventing direct impact. This ensures the structure remains steadfast even in harsh weather, providing safe shelter for its inhabitants. The square doors and windows serve as connections to the outside world, facilitating movement and ensuring ventilation and natural light indoors. The integrated design of the "square and circle" in Mongolian yurts reflects ingenuity, addressing both the practical needs of the Mongolian people and their reverence for and adaptation to the natural environment. [10]. From a graphic design standpoint, the ger's form is a masterful use of contrast and visual hierarchy. The dominant circle of the walls and roof creates a cohesive, enveloping visual field unified "positive space." The square door frame acts as a strong contrasting element, creating a clear "visual entry point" and breaking the uniformity. This composition of circle with integrated square establishes a strong focal point and guides the viewer's gaze, embodying the principle of using contrast to create visual interest and order.

Interior Decoration

The interior decoration patterns of Mongolian yurts often incorporate "square and circle" graphics, showcasing their unique aesthetic appeal and further highlighting their cultural depth. For example, the skylight features a square-textured border resembling an exquisite inlay, with patterns including traditional geometric motifs such as fretwork and swastikas, as well as natural elements like flowers and clouds. The four corners are adorned with intricate carvings and inlaid with colored gems, complementing the circular skylight in a harmonious balance of strength and softness, creating a visually cohesive and elegant effect.

The felt embroidery patterns on the yurt walls are exemplary of the skillful integration of "square and circle" designs. Artisans deftly intertwine these shapes, embroidering a circular sun within a square frame, often with a lotus at the center of the circle, surrounded by orderly arranged square patterns. The vibrant embroidery, typically in colors like red, yellow, blue, and green—tones that harmonize with the grassland landscape—creates a warm and lively atmosphere. The intricate needlework demonstrates the craftsmanship and aesthetic sensibility of Mongolian women, giving the patterns a three-dimensional and dynamic quality.

The hana (lattice framework) is engraved with simple "square and circle" motifs, adding a touch of rustic elegance. Additionally, furniture inside the yurt is adorned with "square and circle" patterns, aligning with the overall stylistic theme and enhancing the harmony of the interior decor.(As shown in the figure 1 and 2)

Fig. 1. Interior of Mongolian yurt.

Fig. 1. Interior of Mongolian yurt.

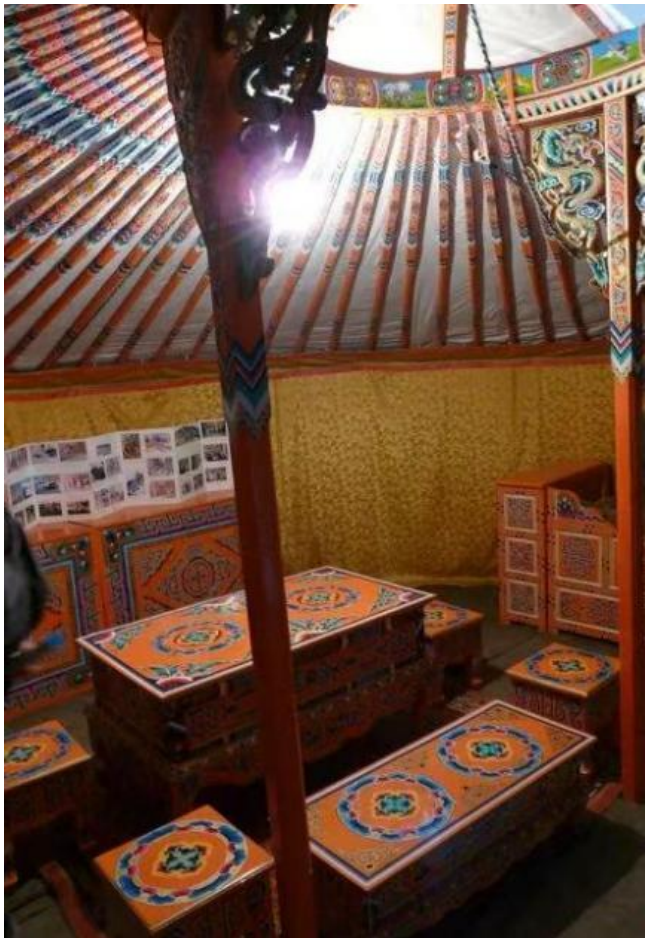


Fig. 2. Interior of Mongolian yurt (Yuna & Toono).



The interior patterns function as a modular grid system. The square frames act as containers or modules, organizing the visual space on walls and furniture. The circular motifs placed inside or between these squares serve as focal points, breaking the strict modularity and creating rhythm and visual punctuation. This interplay establishes a sophisticated visual hierarchy, guiding the inhabitant's gaze from structural elements (square frames) to symbolic centers (circular motifs), effectively applying the design principle of "alignment" within a complex field.

A. "Square and Circle" in Clothing Patterns

"Square and Circle" on Traditional Robes

Mongolian traditional robes fully demonstrate the ethnic wisdom and artistic charm, with the application of "square and circle" patterns being highly skillful. The collar is often adorned with square patterns, featuring smooth lines along the edges. Gold thread is used to create dazzling highlights, while dark-colored silk embroidery adds a three-dimensional effect. The intricate fretwork inside symbolizes longevity and endless continuity, and the swastika pattern represents auspiciousness and embodies hopeful aspirations. Additionally, these patterns help reinforce the collar, extending the robe's lifespan.

The square patterns on the cuffs symbolize the Mongolian respect for order. Arranged neatly, their colors harmonize with the robe's main body. These patterns serve both decorative and reinforcing purposes, symbolizing adherence to rules and traditions in conduct. (As shown in figure 3).

Fig. 3. The use of patterns in clothing.



The square patterns on the collar and cuffs serve as a key function of edge alignment. They create a strong, clear boundary framing the body and garment openings, enhancing the structural definition of the silhouette. This use of repeated square borders exemplifies employing the principle of repetition to create rhythm and unity along edges. Geometric quantification of these patterns often reveals a high degree of symmetry and consistent spacing, indicating an application of measured proportion rather than purely freehand ornamental decoration.

"Square and Circle" on Accessories

The use of "square and circle" patterns in Mongolian accessories such as hats, belts, and boots is skillfully executed. The round crown of the hat symbolizes the vastness and perfection of the sky, while the square patterns on the brim create a contrast between strength and softness. Embellished with embroidery or inlaid gemstones, these hats add a sense of solemnity and festivity when worn during celebrations.

Belts are adorned with "square and circle" patterns, forming decorative bands where squares and circles alternate rhythmically. The colors harmonize with the robes, and the various ways of tying the belt offer diverse visual effects [11].

Boots feature square patterns on the shaft, crafted through leather cutting and stitching for a simple yet three-dimensional effect. Circular patterns on the vamp are embroidered or adorned with metal pieces in vibrant colors that shimmer while walking, embodying bravery and resilience. The circle represents flexibility and freedom, while the square symbolizes determination and forward momentum.

The "square and circle" patterns in Mongolian clothing and accessories are cultural treasures, reflecting the ethnic group's wisdom, aesthetics, and philosophy of life. (As shown in the figure 4 and 5).

Fig. 4. The use of patterns in shoes.



Fig. 5. The use of patterns in shoes.



On belts and hats, the alternation of square and circular motifs creates a distinct visual rhythm, akin to a musical beat. This alternation leverages the contrast in shape perception—the angularity of the square versus the fluidity of the circle—to generate visual interest and movement across the band or surface. This is a direct application of the principle of creating rhythm through alternation, a fundamental technique in graphic design for creating dynamic yet ordered compositions.

B. "Square and Circle" in Utensil Patterns

"Square and Circle" on Saddles

The saddle is a crucial piece of riding equipment, and its decoration serves as an exemplary model of the "square and circle" combination. Artisans use square patterns as the fundamental framework for the saddle bridge, while softening the edges to avoid the abruptness of sharp right angles. Inside the square, cloud patterns symbolize aspirations for a better life. These clouds, with their graceful and flowing curves, represent auspiciousness and freedom.

Geometric lines highlight a sense of bravery and determination. The interlocking lines, strong and dynamic, reflect the characteristics of Mongolian warriors. The application of low-relief and openwork carving techniques gives the patterns a three-dimensional quality, enhancing their clarity and depth. The sun pattern on the saddle seat, positioned at the center and surrounded by radiating motifs, symbolizes light and the energy of life. (As shown in figure 6).

Fig. 6. The use of patterns in saddle.



Saddle decoration is a complex study in structural grid and radial balance. The square or rectangular panels on the pommel and cantle establish an underlying, often invisible grid for organizing decorative elements. The prominent circular sun motif on the seat is the central anchor, from which other visual elements radiate or toward which they converge. This creates a radial balance, a powerful design principle conveying stability, focus, and energy, perfectly suited for an item associated with movement and control.

"Square and Circle" on Bows and Arrows

Bows and arrows, essential tools for hunting and warfare, feature ingeniously designed "square and circle" patterns in their decorations. These carved and engraved motifs reflect the Mongolian people's reverence for natural deities. The patterns are predominantly square-shaped, adorned with dark brown pigments depicting totems such as wolves and eagles, rendered with exquisite and smooth lines. The arrow shafts are wrapped with colorful threads, intricately woven into circular patterns. Concentric circles, nested layer upon layer, symbolize unity and convergence, representing the strength of the Mongolian people and showcasing their closely-knit, collaborative spirit. The lifelike depictions of animals demonstrate a balance of skill, not only enhancing friction but also improving shooting accuracy, highlighting the Mongolian people's mastery in balancing practicality and aesthetics. (As shown in figure 7)

Fig. 7. The use of patterns in bows and arrows.



In this study, semiotic function is tightly interwoven with ergonomic signaling. The square-based carvings on the bow grip are often aligned with hand placement points, leveraging the shape's association with stability and firmness to visually signal "grip here." The concentric circles on the arrow shaft, beyond their symbolic meaning, create a textural pattern to enhance grip. This exemplifies how graphic design elements serve not only decoration but also functional communication and tactile guidance.

"Square and Circle" on Milk Buckets

Milk buckets, indispensable companions in daily life, feature patterns that harmoniously blend "square and circle" elements. The bucket bodies are painted with square patterns and pastoral scenes, reflecting the Mongolian people's love for life. Artisans often employ relief and openwork carving techniques on wooden milk buckets, giving the patterns a raised, three-dimensional effect. Metal milk buckets, on the other hand, highlight their unique metallic texture, with craftsmen using engraving and inlay techniques to create intricate and delicate patterns [12]. The circular patterns on the bucket lids carry profound symbolism: lotus motifs symbolize purity and nobility, representing a clear and virtuous life, while auspicious signs convey wishes for prosperity. The strategically arranged patterns add charm and rhythm. These designs not only enhance artistic appeal but also serve practical purposes. For instance, the circular lotus petal patterns provide a non-slip surface, making it easier to open and close the lid, embodying the Mongolian people's wisdom and creativity in daily life. The milk bucket presents a clear case of figure-ground relationship manipulation. The square patterns on the cylindrical body often create an illusion of flattening or segmenting on the curved surface, playing with perception. The central circular motif on the lid is a definitive focal point, immediately drawing the eye. Furthermore, the function of the circular pattern providing a non-slip surface is a prime example of form following function, where the graphic design (the raised circular pattern) is intrinsically linked to the product's usability.

VI. CONCLUSION

This study expands the existing body of knowledge on Mongolian patterns by systematically applying a graphic design lens. While scholars like Lujin (2022) and Tsogt (2019) have expertly decoded the cosmic and cultural symbolism of these motifs, our analysis reveals the underlying visual syntax that allows this symbolism to be communicated. For instance, the "unity of heaven and earth" they describe is constructed visually through the consistent application of principles like contrast (square vs. circle) and balance (static vs. dynamic), which are universal in visual communication.

Our geometric quantification provides empirical support for the observed design intentionality. The high degrees of symmetry and consistent proportions measured in the motifs, such as the near-perfect circularity index of central sun motifs and the spatial frequency of repeating border patterns, indicate a tradition governed by precise visual norms, not arbitrary decoration. This aligns with the methodological innovations of Gantuya et al. (2025) but grounds the mathematical models in observed traditional artifact forms rather than generated morphologies.

The theoretical frameworks proposed by Mongolian scholars Р.Гоцбаяр (R.Gotsbayar) and Б.Энхбат (B.Enkhbat) provide a critical bridge for our discussion. R.Gotsbayar's semiotic model of ornamentation as a grammatical language finds direct proof in our identification of the pervasive compositional rule, square as frame, circle as center, found consistently across diverse artifacts. This rule functions as a fundamental "sentence structure" within this visual language. B.Enkhbat's work on algorithmic generation resonates with our identification of the modular grid systems in interior decoration, suggesting a logic akin to modern modular design adopted by traditional artisans.

From the perspective of graphic design theory, the Mongolian "square and circle" system demonstrates a profound, pre-codified understanding of Gestalt principles. The use of squares to create proximity and grouping of elements, and circles to invoke closure and continuity, shows an intuitive grasp of how humans perceive organized wholes. This challenges the notion that such principles are solely products of modern design education.

Limitations and Future Research: This study is primarily based on the visual analysis of historical artifacts. Future research would benefit from ethnographic methods, such as interviews with master artisans, to gain deeper insight into the intentionality behind compositional choices. Furthermore, the quantitative analysis presented here is descriptive; future work could employ statistical methods (e.g., cluster analysis) on larger datasets to formally categorize pattern types based on geometric features. Testing the perceptual impact of these traditional motifs versus their modern reinterpretations through user experience studies would be a valuable direction for applying these findings to contemporary design practice.

This study demonstrates that the "square and circle" motifs in traditional Mongolian patterns constitute a sophisticated graphic design system, not merely a collection of decorative symbols. Through visual, semiotic, and geometric analyses, we have decoded how these elements operate according to universal design principles—such as contrast, balance, rhythm, alignment, and focal point creation—to convey profound cultural philosophies and structure the visual environment.

The primary conclusion is that Mongolian traditional art inherently embodies core principles of graphic design, using a formal visual language to organize space, guide perception, and communicate complex ideas. This graphic system served as a versatile tool for identity expression, functional signaling, and cosmological representation across architecture, clothing, and tools. (As shown in the figure 8)

Based on these findings, we propose the following evidence-based suggestions:

1. For Cultural Heritage & Education: Develop educational modules that teach traditional Mongolian

patterns not only as cultural history but as fundamental graphic design principles . This can enable a new generation of designers to draw from this heritage with a deeper, methodological understanding.

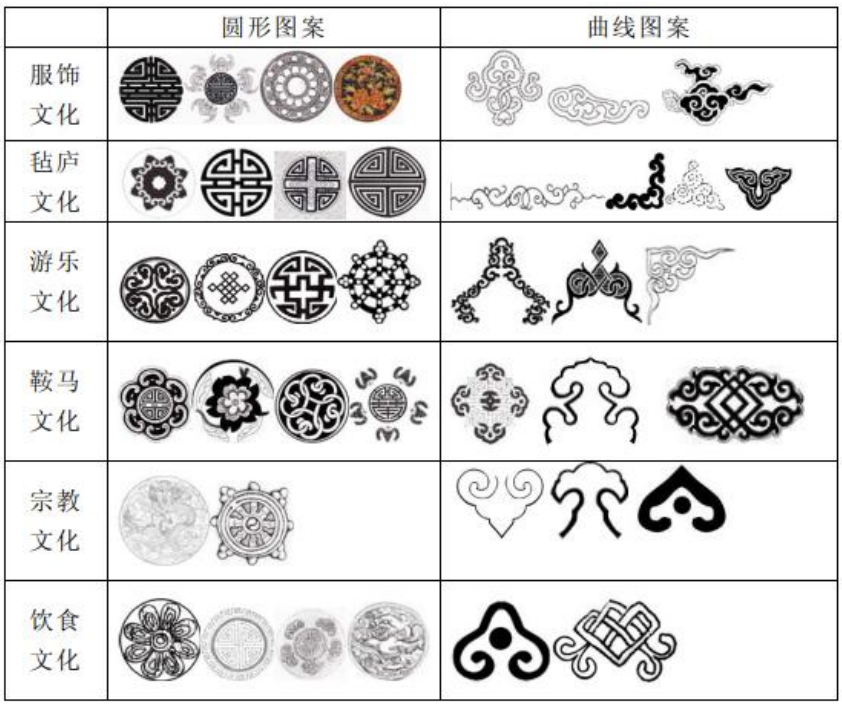
2. For Contemporary Design Practice: Create a "Mongolian Geometric Design Language" toolkit for modern designers. This would involve abstracting the identified formal rules (e.g., the framing function of squares, the focusing function of circles, specific rhythmic alternations) into reusable design assets, grid templates, and style guides applicable to branding, textile design, and architectural detailing.

3. For Interdisciplinary Research: Encourage collaboration between design theorists, historians, and computer scientists to build generative design models based on the quantified geometric and compositional rules identified in this study. This could lead to innovative tools for both preservation and creative extension of the traditional visual vocabulary.

4. For Future Academic Study: Conduct comparative studies with other nomadic or traditional graphic systems to identify the unique versus universal characteristics of the Mongolian "square and circle" syntax. Furthermore, experimental studies should be designed to test the perceptual efficacy of these traditional compositional rules within modern media contexts.

Through these applied and research-oriented efforts, the graphic design of "square and circle" in Mongolian traditional patterns can transcend its historical context, offering timeless principles and a rich formal vocabulary for shaping the future of visual communication and cultural expression.

Fig. 8. The use of patterns in bows and arrows.



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Сүлжээний халдлага илрүүлэх, сэргийлэх нээлттэй эхийн системийг ашиглах судалгаа

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***Хураангуй* — Өдөр бүр тохиолдож байгаа сүлжээний аюул занал нь кибер аюулгүй байдалд үүсэж буй маш том эрсдэл, санхүүгийн дарамт болж байна. Тиймээс худалдааны шийдлүүдээс илүү өртөг багатай, хялбар, хэрэглэгчид ээлтэй, өөрсдийн нөхцөлд тохируулан ашиглах боломжтой нээлттэй эхийн аюулгүй байдлын шийдлүүдийг туршиж үзэх шаардлагатай болоод байна. Энэхүү өгүүлэлд нээлттэй эхийн халдлага илрүүлэх систем (IDS) болон халдлагаас сэргийлэх систем (IPS) болох Suricata шийдлийн давуу болон сул талуудын талаар авч үзэн open-source IDS/IPS системийн ажиллах зарчмыг тайлбарлаж, туршилтын ажлыг гүйцэтгэх болно [1].**

Түлхүүр үг—Open-Source IDS/IPS, Denial-of-Service Attack, Hping3 Tool, Suricata

I. Удиртгал

Дэлхий дахинд кибер орон зайн хэрэглээ жил ирэх тусам ихсэж байна. Олон улсын статистик, судалгааны нэгдсэн сайт (Statista)-ын 2025 оны 2 дугаар сарын байдлаар гаргасан тайланд дэлхий даяар 5.56 тэрбум интернет хэрэглэгч байгаа нь дэлхийн хүн амын 67.9 хувийг эзэлж байна. Үүний 5,24 тэрбум нь нийгмийн сүлжээний хэрэглэгчид бөгөөд үлдсэн 2.63 тэрбум хүн сүлжээнд ороогүй байна [2].

SecureWorks-ийн 2024 оны 11 дүгээр сарын тайланд дурдсанаар дэлхий даяар кибер гэмт хэргийн хохирол 2025 он гэхэд 10.5 их наяд ам.долларт хүрнэ гэж таамаглаж байна. Энэ үр дүн нь санхүүгийн томоохон алдагдалд хүргэж болзошгүй бөгөөд үүнээс урьдчилан сэргийлэхийн тулд албан байгууллагууд IDS болон IPS зэрэг аюулгүй байдлын дэвшилтэт шийдлүүдийг ашиглан арга хэмжээ авах шаардлагатай байгааг харуулж байна [3].

Судалгаанаас үзэхэд IDS шийдлийн халдлага илрүүлэх түвшин нь 80%-иас 98% хүртэл байдаг байна. IPS шийдлийг нэвтрүүлсэн байгууллагын зөрчилд хариу үйлдэл үзүүлэх хугацаа 50%-иас 75% хүртэл буурдаг байна. IPS нь халдлагыг илрүүлж, хамгаалах явцыг автоматжуулснаар илрүүлэхээс эхлээд хариу арга хэмжээ авах хүртэлх хугацааг бууруулдаг юм.

Verizon-ооc гаргасан Мэдээллийн зөрчлийн судалгааны тайланд дурдсанаар, зөрчлийн 70 орчим хувь нь гаднаас чиглэсэн халдлагууд байсан бөгөөд IDS болон IPS нь хортой программ, ransomware зэрэг гадны аюулыг илрүүлэхэд чухал үүрэг гүйцэтгэдэг талаар дурдсан [4]. Тиймээс энэхүү өгүүлэлдээ сүлжээний халдлага илрүүлэх, халдлагаас сэргийлэх нээлттэй эхийн системүүдийг аюулгүй байдлын шийдэл болгон ашиглах давуу талуудыг судалгаа, шинжилгээнд тулгуурлан гаргаж, ажиллах зарчмыг харуулах туршилтын ажлыг гүйцэтгэх болно.

II. Судалгааны тойм

Монгол Улсад сүлжээний аюулгүй байдал, халдлага илрүүлэх системийн талаар хэлэлцүүлэг нэмэгдэж буй хэдий ч уг чиглэлээр онолын үндэслэлтэй, туршилтад суурилсан судалгаа, практик хэрэгжилт харьцангуй цөөн байна.

Багш Г.Гандэмбэрэл, судлаач С.Отгонлхагва нар [5] халдлага эсэргүүцэх системийн тухай зарим туршилт судалгаа хийсэн бөгөөд тэд нээлттэй эхийн Snort системийг диамонд хэлбэрээр ажиллуулж туршсан байдаг. Мөн, профессор Ө.Эсболдын удирдлага дор судлаач Б.Бямбадорж [6] нь утасгүй сүлжээний халдлага илрүүлэх системийн талаар судалгааны ажил хийж гүйцэтгэсэн ба утасгүй сүлжээний зохицуулагч дээр сүлжээний бүх урсгалыг нээлттэй эхийн Snort системийг суулгаж, тохируулсан компьютер руу чиглүүлэлт хийх программ бичих замаар хэрэгжүүлсэн байдаг.

Олон улсын түвшинд кибер аюулгүй байдлыг хангах олон шийдлүүд байдаг ч тэдгээр нь ихэвчлэн төвөгтэй, өндөр өртөгтэй бөгөөд жижиг, дунд байгууллага, хөгжиж буй орнуудад хэрэглэхэд хүндрэлтэй байдаг.

Li.W, Shengfeng.T. [7] Судалгаанд халдлага илрүүлэх систем (IDS)-ийн alert буюу сэрэмжлүүлгийн мэдээллийг онтологоор (ontology) боловсруулах preprocessor системийг танилцуулсан. Судалгааны гол зорилго нь олон төрлийн IDS-аас ирж буй сэрэмжлүүлгийг автоматаар, уялдуулан нэгтгэж, давхардал болон алдаа (false positive)-г бууруулахад оршдог. Мөн, Asad.H, Gashi.I. [8] Нээлттэй эхийн буюу open-source IDS-үүдийн олон янз байдал, төрөлжүүлэлт, давуу болон сул талуудыг шинжлэх ухааны үндэслэлээр судалсан. Судалгааны гол зорилго нь IDS-ийн төрөл бүрийн архитектур, алгоритм, илрүүлэх хэв маяг (signature-based, anomaly-based, hybrid) болон нээлттэй эхийн IDS-ийг хэрэглэх боломж, тохиромжтой хэрэглээний нөхцлийг тодорхойлох явдал байсан.

Халдлага илрүүлэх, сэргийлэх нээлттэй эхийн системүүдийн нэгэн шийдэл болох Suricata-г ашиглан туршилт хийж байгаа нь манай судалгааны ажлын онцлог тал юм.

Энэхүү судалгааны зорилго нь нээлттэй эхийн сүлжээний халдлага илрүүлэх системүүд нь бодит орчинд түгээмэл тохиолддог сүлжээний халдлагуудыг хэр найдвартай, богино хугацаанд илрүүлж, хариу арга хэмжээ авах боломжтой эсэхийг туршилтаар үнэлэхэд оршино. Судалгаанд ашигласан арга зүйг давтан гүйцэтгэх боломжтой байдлаар зохион байгуулж, туршилтын орчин, ашигласан системүүд, халдлагын төрөл болон тохиргоонуудыг тодорхой тайлбарласан.

Арга зүйг сонгосон шалтгаан нь туршилтад ашигласан халдлагын төрлүүд нь байгууллагын сүлжээний орчинд түгээмэл тохиолддог, бодит эрсдэл өндөртэй халдлагууд байсантай холбоотой юм. Иймд энэхүү судалгаа нь нээлттэй эхийн халдлага илрүүлэх системийн гүйцэтгэл, найдвартай байдал болон бодит орчинд хэрэгжих боломжийг туршилтаар нотолсон шинжлэх ухааны үндэслэлтэй үр дүнг санал болгож байна.

III. Халдлага илрүүлэх, сэргийлэх систем

Чөлөөт буюу нээлттэй эхийн программ хангамж гэдэг нь хэн ч эх кодыг үзэх, судлах, үнэлэх дүгнэх болон шинэчлэн өөрчлөх боломжтой байдаг программ хангамж юм. Эх код нээлттэй байдаг учир хэн ч сайн дураараа программ хангамжийн дизайныг сайжруулах үйл ажиллагаанд оролцох боломжийг олгодог бөгөөд хаалттай эхийн программ хангамж нь хувилах эрх нь хязгаарлагдмал, эх код нь хэрэглэгчдэд харагддаггүй, патенттай өмчийн программ хангамжаас ялгаатай юм. Нээлттэй эхийн программ хангамжийг ашиглахын давуу талууд нь программ хангамж бүтээх зардлыг бууруулах, хамгаалалт болон тогтвортой байдлыг өндөрсгөх, хэрэглэгчдэд өөрсдийн техник хангамжаа илүү сайн удирдах боломж олгодог зэрэг юм.

Мөн нээлттэй эхийн үйлдлийн систем болох Linux нь өнөөдөр олон хүнд ашиг тусаа өгч, серверүүд, суурин компьютер, ухаалаг утсууд зэрэг олон төхөөрөмжүүдийг ажиллуулсаар байна.

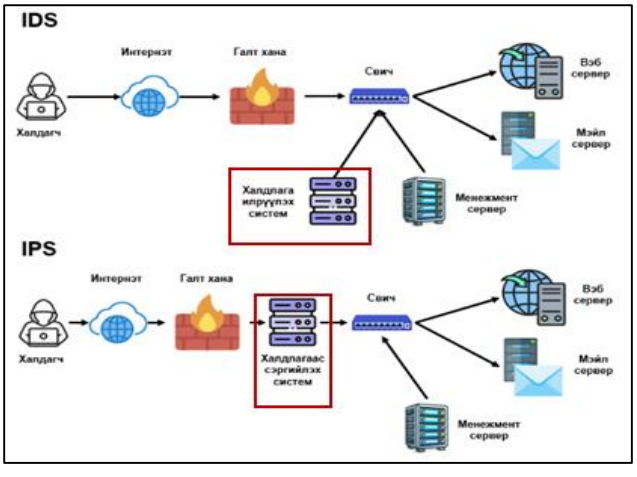


Fig. 1. IDS/IPS-ийн ажиллах зарчим

1-р зураг. IDS/IPS-ийн ажиллах зарчим

Байнгын хувьсан өөрчлөгдөж буй цахим аюулгүй байдлын орчинд хэрэглэгчдийн нууц мэдээлэл, эмзэг датаг хамгаалах нь байгууллага болон хувь хүний хувьд хамгийн чухал зорилт болоод байгаа билээ. Энэхүү аюулгүй байдлын тогтолцооны нэгэн чухал бүрэлдэхүүн хэсэг нь халдлага илрүүлэх систем (IDS) ба халдлагаас сэргийлэх систем (IPS) юм.

TABLE I. Нээлттэй эхийн IDS/IPS [9]

д/д	*Халдлага илрүүлэх, сэргийлэх систем*	*Үнэлгээ*
1	Snort	9.1
2	Suricata	9
3	Zeek (Bro)	8.9
4	Maltrail	8.5
5	Security Onion	7.6
6	Kismet	7
7	Psad	6.8
8	Sagan	6.3

[a] Нийт 10 онооноос үнэлсэн болно.

Intrusion Detection System (IDS) – IDS нь сүлжээнд заналхийлсэн аливаа халдлага, сэжигтэй тохиолдлыг илрүүлж анхааруулга, мэдэгдлийг өгдөг болов ч тэдгээрийг блок хийх эсвэл зогсоох арга хэмжээ авдаггүй.

A. Халдлага илрүүлэх систем (IDS)

IDS нь сүлжээний урсгалыг сэжигтэй үйлдэл, аюулгүй байдлын нийтлэг зөрчлийг зөрчиж буй эсэхийг хянаж, болзошгүй халдлага, сэжигтэй үйлдэл сүлжээнд илэрсэн үед мэдээлэх, анхааруулах зарчмаар ажилладаг.

IDS-д гурван үндсэн төрөл байдаг:

- Сүлжээнд суурилсан IDS (NIDS): Network-based IDS (Сүлжээний орчинд шаардлагатай хэсэгт суурилагдаж сүлжээг бүхэлд нь хянах зориулалттай.)
- Хостод суурилсан IDS (HIDS): Host-based IDS (Ямар нэгэн хост, сервер дээр тусгайлан суурилагдаж, тухайн суусан хост, серверийн сүлжээнд анализ хийх зарчмаар ажилладаг.)
- Вэбд суурилсан IDS (WIDS): Web-based IDS (Вэб программууд болон түүний сүлжээний урсгал руу чиглэсэн халдлагыг илрүүлэхэд онцгойлон анхаарч ажилладаг.)

B. Халдлагаас сэргийлэх систем (IPS)

IDS системээс ялгаатай нь сэжигтэй үйлдлийг илрүүлээд зогсохгүй тэдгээр халдлагаас сэргийлэх, хамгаалах арга хэмжээг авах боломжтой.

IPS нь мөн адил сүлжээнд суурилсан эсвэл хост дээр суурилсан байж болно. IPS нь сүлжээний пакетуудыг шалгаж, сэжигтэй үйлдэл илэрсэн тохиолдолд тухайн пакетыг блок хийх, холболтыг дахин эхлүүлэх, холбогдож буй эх үүсвэрийг хаах зэрэг яаралтай арга хэмжээг автоматаар авдаг ба энэ нь цаашлаад сүлжээнд ажиллаж буй аливаа сервер, сүлжээний төхөөрөмж зэргийг сүлжээний түвшний түгээмэл халдлагад өртөх, цаашлаад Application системийн түвшний халдлагад өртөхөөс урьдчилан сэргийлдэг энгийн бөгөөд үр дүнтэй аюулгүй байдлын системүүд юм.

C. Snort (Нээлттэй эхийн IDS/IPS)

Snort-ийг 1998 онд Мартин Рош бүтээсэн бөгөөд сүлжээний халдлага илрүүлэх, сэргийлэх нээлттэй эхийн систем юм.

Snort-ийг гурван өөр аргаар хэрэглэж болно; tcpdump, пакет бүртгэгч эсвэл сүлжээний халдлагыг илрүүлэх, урьдчилан сэргийлэх систем гэх мэт пакет sniffer. Пакет sniffer болгон ашиглах үед Snort нь сүлжээний пакетуудыг уншиж, консол дээр харуулах ба пакет бүртгэгчийн хувьд Snort нь пакетуудыг диск рүү бүртгэх болно. Халдлага илрүүлэх горимд энэ нь сүлжээний урсгалыг хянаж, хэрэглэгчийн тодорхойлсон дүрмийн дагуу урсгалыг шинжлэх болно [10].

D. Zeek/Bro (Нээлттэй эхийн IDS/IPS)

Bro нь 1998 онд Верн Пакссон үүсгэн байгуулагдсан бөгөөд нээлттэй эхийн UNIX дээр суурилсан сүлжээний халдлагыг илрүүлэх систем юм.

Bro идэвхгүй сүлжээний урсгалыг хянаж, хортой урсгалыг хайж байдаг. Энэ нь эхлээд сүлжээний траффикийг задлан шинжлэх замаар халдлагыг илрүүлж, дараа нь үйлдлийг хортой гэж үзсэн загвартай харьцуулахад чиглэсэн анализаторуудыг ажиллуулдаг. Шинжилгээнд тодорхой халдлага (гарын үсэг, үйл явдал) болон ер бусын үйл ажиллагаа (гажиг) илрүүлэх зэрэг орно.

Bro нь ихэвчлэн сүлжээний гол уулзвар дээр байрладаг бөгөөд энэ нь ирж буй болон гарч буй бүх урсгалыг хянах боломжтой. Bro нь сүлжээний урсгалыг цуглуулах, шүүх, дүн шинжилгээ хийх зэрэг функцуудыг хангадаг. Энэ нь түгээмэл протоколуудын нарийвчилсан дүн шинжилгээ хийх чадвартай бөгөөд энэхүү шинжилгээний үр дүн нь ажиглагдсан үйл ажиллагааг дүрсэлсэн хэд хэдэн үйл явдал юм [11].

E. Suricata (Нээлттэй эхийн IDS/IPS)

Suricata бол 'Нээлттэй мэдээллийн аюулгүй байдлын сангаас' боловсруулсан нээлттэй эх сурвалжийн халдлагыг илрүүлэх, сэргийлэх систем юм. Бета хувилбар нь 2009 оны 12-р сард гарсан бол анхны тогтвортой хувилбар нь 2010 оны 7-р сард гарсан. Suricata нь халдлагыг илрүүлэх талбарт шинэ санаа, технологийг нэвтрүүлэх зорилгоор бүтээгдсэн.

Нээлттэй Мэдээллийн Аюулгүй байдлын Сан (OISF) нь Suricata-д халдлага илрүүлэх, сэргийлэх дүрмийн багцыг олгодог бөгөөд аюулгүй байдлын оновчтой түвшинг хадгалах үйл явцыг Suricata-ийн тусламжтайгаар хялбаршуулдаг [12].

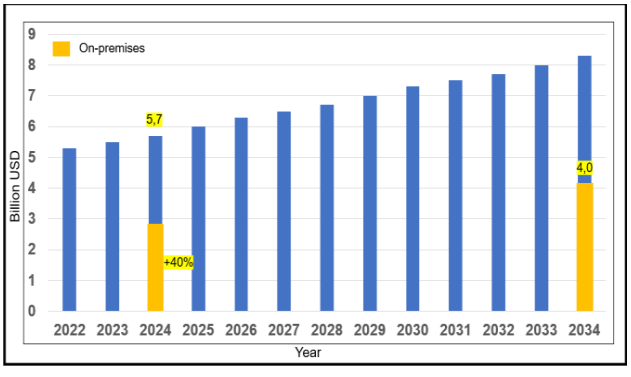


Fig. 2. Худалдааны IDS/IPS-ийн зах зээлийн өсөлтийн үзүүлэлт, тэрбум ам.доллараар гаргасан байдал

Дэлхийн халдлага илрүүлэх, урьдчилан сэргийлэх систем (IDS/IPS)-ийн зах зээл 2024 онд 5.7 тэрбум ам.долларын үнэлгээтэй байсан бөгөөд 2025–2034 оны хооронд жил бүрийн нийлмэл өсөлтийн түвшин (CAGR) 7.3 хувьтайгаар өсөх тооцоололтой байна. Байршуулах хэлбэрийн ангиллаар авч үзвэл уг зах зээл нь дотоод суурилуулалттай, үүлэн орчинд суурилсан болон холимог загвар гэсэн гурван үндсэн сегментэд хуваагдана. 2024 онд дотоод суурилуулалт бүхий сегмент нийт зах зээлийн 40 хувиас давсан эзлэх хувьтай байж, 2034 он гэхэд 4 тэрбум ам.долларын үзүүлэлтийг даван өсөх төлөвтэй байна [13].

Сүлжээний TCP 80 порт дээр дотогшоо нэвтрэх боломжийг олгодог галт ханын дүрэм нь дотоод вэб серверт алсаас хандах боломжийг олгоно. Халдагчид вэб сервер рүү халдахдаа HTTP портыг ашиглаж болно. Энэ хувилбарт IDS нь вэб траффикийн гарын үсэг болон сайн мэддэг халдлагын гарын үсгийн мэдээллийн сангийн хооронд харьцуулалт хийх замаар хууль ёсны траффик (зөвшөөрөгдсөн холболтууд) болон вэб сервер рүү халдахыг оролдсон хоорондын ялгааг тодорхойлж чадна. Энд IDS нь сүлжээний администраторт ийм халдлагын талаар мэдэгдэж, зохих арга хэмжээ авахыг анхааруулж, чухал үүрэг гүйцэтгэдэг.

Сүлжээний халдлага илрүүлэх систем (IDS) нь аюулгүй байдлын хамгаалалтын хамгийн өргөн хэрэглэгддэг хэрэгслүүдийн нэг юм. Эдгээр IDS-ийн зарим нь нээлттэй эх үүсвэртэй бөгөөд хамгийн өргөн хэрэглэгддэг нээлттэй эхийн IDS нь Snort болон Suricata юм. Эдгээр хоёр хэрэгсэл нь гарын үсэгт суурилсан болон хорлонтой үйл ажиллагааг тодорхойлох дүрэмд тулгуурладаг. Дүрмүүд нь агуулга, протокол, порт гэх мэт, түүнчлэн үйл ажиллагаа/траффикийн гарал үүсэлтэй холбоотой хортой үйл ажиллагааг тодорхойлдог - энэ тохиолдолд сэжигтэй IP хаягуудыг "хар жагсаалтад" оруулж, эдгээр IP хаягаас гаралтай траффик илэрвэл анхааруулга өгдөг. IDS-ийн тохиргооноос хамааран траффикийг сэрэмжлүүлэх боловч траффикийг зөвшөөрөх, эсвэл сэрэмжлүүлэг өгч зогсоохын тулд IDS нь халдлагаас урьдчилан сэргийлэх систем (IPS)-ийн горимд ажиллаж байх ёстой.

IPS нь довтолгооны оролдлогын үед зохих арга хэмжээг автоматаар авах замаар чухал үүрэг гүйцэтгэдэг. Жишээлбэл, вэб сервертэй холболтыг таслах / хаах. Тиймээс IDS нь халдлагын оролдлого эсвэл хортой үйлдэл гарсны дараа бүртгэл үүсгэж, сүлжээний администраторт сэрэмжлүүлэх замаар идэвхгүй үйлдэл хийдэг бол IPS нь эдгээр үйл ажиллагааг идэвхтэй хянаж, сүлжээг хамгаалахын тулд эдгээр үйл ажиллагааны эсрэг арга хэмжээ авдаг. Тиймээс IDS болон IPS нь компьютерийн сүлжээг хамгаалах сүлжээний түвшний хамгаалалтын үүрэг гүйцэтгэдэг.

IV. Хэрэгжүүлэлт

Уг туршилтын ажлаар үйлдлийн системүүдийг үүсгэж, халдлага илрүүлэх, сэргийлэх Suricata системийг суулган тохиргоо хийж, сүлжээнд туршилтаар халдлага хийн үр дүнг харах болно.

Энэхүү судалгаанд хүн болон амьтан оролцоогүй, хувь хүнийг таних боломжтой ямар нэгэн өгөгдөл ашиглаагүй болно. Иймд ёс зүйн зөвшөөрөл болон мэдээлэлд суурилсан сайн дурын зөвшөөрөл шаардагдаагүй. Судалгааг олон нийтэд нээлттэй, нээлттэй эхийн систем болон эх сурвалжуудыг ашиглан гүйцэтгэсэн.

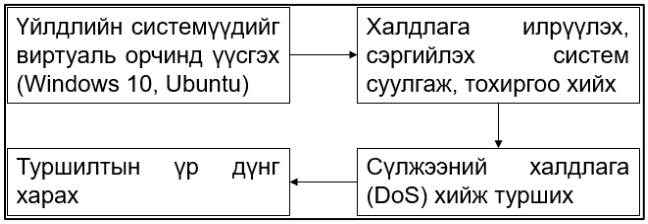


Fig. 3. Туршилтын ажлын ерөнхий бүтэц

Туршилтын ажлыг гүйцэтгэхэд дараах төхөөрөмж, үйлдлийн систем, халдлагын хэрэгслийг ашигласан. Үүнд:

a) Зөөврийн компьютер (Dell G15, i5-13450, Memory 16gb, Disk 512gb SSD)

b) Виртуаль үйлдлийн систем (VMWare Workstation Pro-д Ubuntu, Windows 10 үүсгэх)

c) Нээлттэй эхийн систем (Suricata)

d) Халдлагын хэрэгсэл (hping3)

e) Халдлагын төрөл (Denial-of-Service /DoS/)

A. Туршилтын орчныг бэлдэх, халдлага илрүүлэх, сэргийлэх нээлттэй эхийн системийг суулгах

Энэхүү туршилтад нийт гурван виртуал машиныг ашигласан. Виртуал машинууд нь гадаад сүлжээнээс бүрэн тусгаарлагдсан бөгөөд зөвхөн host-only адаптерээр дамжин хоорондоо холбогдож, шууд харилцаа тогтоохоор тохируулсан. Сүлжээний урсгалыг хянах зорилгоор хяналтын виртуал машиныг man-in-the-middle хэлбэрээр ашигласан.

Хяналтын зориулалттай эхний виртуал машин нь Ubuntu 24.04.2 LTS (64-bit) үйлдлийн системтэй (Monitor), хамгаалалтын зориулалттай хоёр дахь виртуал машин нь Windows 10 Pro (64-bit) үйлдлийн системтэй (User), харин халдлага гүйцэтгэх зориулалттай гурав дахь виртуал машин нь Kali Linux 2025.2 үйлдлийн системтэй (Attacker) байна.

Хамгаалагдсан хэрэглэгчийн сүлжээний хаягийг Windows Command Prompt орчныг ашиглан тодорхойлсон. Сүлжээний мониторинг болон халдлага илрүүлэх зорилгоор хяналтын виртуал машин дээр нээлттэй эхийн халдлага илрүүлэх, сэргийлэх системүүд болох Snort болон Suricata-г суурилуулан ашигласан.

Командууд: [12]

```
sudo add-apt-repository ppa: oisf/suricata-stable
sudo apt update
sudo apt-get update && sudo apt-get install suricata
```

B. Suricata IDS/IPS-д тохиргоо хийх

Туршилтын орчинд Suricata халдлага илрүүлэх системийг суурилуулсны дараа түүний дүрмийн удирдлагыг тохируулан, шинээр rules директор үүсгэж хяналтын дүрмүүдийг боловсруулсан. Энэхүү директор нь сүлжээний урсгалд хийгдэх хяналт, халдлага илрүүлэх логикийг тодорхойлох зориулалттай бөгөөд туршилтад ашигласан халдлагын төрөлд тохирсон дүрмүүдийг багтаасан.

Хяналтын дүрмүүдийг боловсруулахдаа сүлжээний пакетын толгой мэдээлэл, протоколын төрөл, эх үүсвэр болон зорилтот хаяг, портын дугаар, мөн халдлагад хамаарах онцлог хэв шинжүүдийг харгалзан үзсэн. Үүсгэсэн дүрмүүд нь тодорхой нөхцөл хангагдсан тохиолдолд сэжигтэй үйлдлийг илрүүлж, бүртгэх болон шаардлагатай үед анхааруулга үүсгэх байдлаар ажиллахаар тохируулагдсан.

Ингэснээр Suricata систем нь бодит цагийн горимд сүлжээний урсгалыг хянаж, туршилтад гүйцэтгэсэн халдлагуудыг үр дүнтэй илрүүлэх боломжтой болсон. Хяналтын дүрмүүдийг туршилтын явцад шаардлагатай тохиолдолд шинэчилж, сайжруулснаар илрүүлэлтийн нарийвчлал болон найдвартай байдлыг нэмэгдүүлсэн.

Командууд: [12]

```
cd /var/lib/
sudo mkdir suricata
cd suricata
sudo mkdir rules
sudo mv custom.rules /var/lib/suricata/rules
cd /var/lib/suricata/rules
sudo nano custom.rules
```

C. Сүлжээний халдлага хийж ажиллагааг турших

Сүлжээний орчин дахь эмзэг байдлыг тодорхойлох зорилгоор Nmap хэрэгслийг ашиглан зорилтот хэрэглэгчийн порт болон үйлчилгээний түвшний шинжилгээг гүйцэтгэсэн. Уг шинжилгээний явцад нээлттэй болон эмзэг байж болзошгүй портуудыг илрүүлж, тэдгээр дээр ажиллаж буй үйлчилгээний төрөл, хувилбарын мэдээллийг тодорхойлсон.

Nmap-аар олж илрүүлсэн үр дүнд үндэслэн бодит орчинд түгээмэл тохиолддог халдлагын сценарийг сонгон авч, туршилтын халдлагыг гүйцэтгэсэн. Халдлагын явцад сүлжээний урсгал, пакетын бүтэц болон халдлагын хэв шинжүүдийг Suricata халдлага илрүүлэх систем бодит цагийн горимд хянаж, илрүүлэлтийн чадварыг үнэлсэн.

Энэхүү туршилт нь эмзэг портууд дээр чиглэсэн халдлагыг нээлттэй эхийн халдлага илрүүлэх систем хэр үр дүнтэй илрүүлж, хариу арга хэмжээ авах боломжтой эсэхийг бодит нөхцөлд туршилтаар шалгах боломжийг бүрдүүлсэн.

Командууд: [14]

```
nmap -Pn 192.168.152.136
sudo hping3 -S –flood -V -p 135 192.168.152.136
```

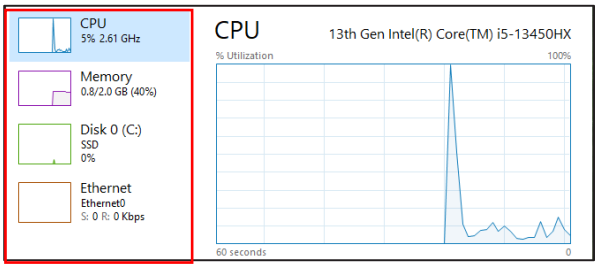


Fig. 4. Туршилтын өмнө компьютерын ачаалал

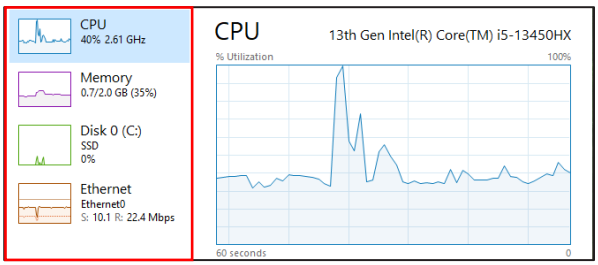


Fig. 5. Туршилтын үеийн компьютерын ачаалал

D. Сүлжээний халдлагыг Suricata IDS/IPS ашиглан хянах

DoS төрлийн халдлагыг илрүүлэх зорилгоор Suricata системд зориулсан тусгай хяналтын дүрмүүдийг боловсруулж, тохиргоонд нэвтрүүлсэн. Эдгээр дүрмүүд нь тодорхой хугацаанд зорилтот систем рүү их хэмжээний сүлжээний хүсэлт илгээгдэж буй хэв шинжийг илрүүлэхэд чиглэсэн бөгөөд пакетын давтамж, эх үүсвэрийн хаяг, портын дугаар зэрэг шалгуур үзүүлэлтүүдэд тулгуурлан ажиллахаар зохион байгуулагдсан.

Хяналтын дүрмүүдийг идэвхжүүлсний дараа туршилтын DoS халдлагыг гүйцэтгэж, Suricata системийн лог бүртгэлийн хэсэгт үүссэн анхааруулга болон бүртгэлийн мэдээллийг шинжилсэн. Лог өгөгдөлд халдлагын эхлэх хугацаа, ашигласан протокол, эх үүсвэр болон зорилтот хаяг, илрүүлсэн халдлагын төрөл зэрэг мэдээллүүд бүртгэгдсэн бөгөөд эдгээр нь халдлага амжилттай илрүүлэгдсэнийг нотолж байна.

Ийнхүү лог бүртгэлийн үр дүнд тулгуурлан DoS халдлагыг илрүүлэх дүрмүүдийн үр ашиг, илрүүлэлтийн найдвартай байдал болон бодит орчинд хэрэгжих боломжийг туршилтаар үнэлэх боломж бүрдсэн.

Командууд: [12]

alert tcp any any -> $HOME_NET any (msg:”Possible Denial-of-Service attack!”; flags:S; flow:stateless; threshold:type both, track by_dst, count 200, seconds 1; sid:10001; rev:1;)

sudo suricata -c /etc/suricata/suricata.yaml -i ens33

sudo tail -f /var/log/suricata/fast.log

V. Үр дүн

Энэхүү судалгааны хүрээнд сүлжээний халдлагын туршилтыг гүйцэтгэж, халдлагыг илрүүлэх болон халдлагаас сэргийлэх чадварыг Suricata систем дээр туршин үнэллээ. Туршилтын үр дүнгээс харахад хэрэгжүүлсэн халдлагуудыг Suricata систем амжилттай илрүүлж, улмаар халдлагын нөлөөллийг бууруулах, сэргийлэх боломжтой болох нь батлагдсан. Энэ нь уг систем бодит орчинд сүлжээний аюулгүй байдлыг хангахад үр дүнтэй ашиглагдах боломжтойг харуулж байна.

Туршилтын хэрэглэгч рүү зөвхөн нэг хостоос халдлага хийхэд процессорын болон сүлжээний ачаалал ойролцоогоор 10-20 дахин нэмэгдсэн байна. Үүнээс дүгнэхэд олон тооны хостоос зэрэг халдлага хийсэн тохиолдолд тухайн хэрэглэгч эсвэл серверийг үйлчилгээнээс бүр мөсөн гаргах боломжтой гэсэн үг юм. Уг халдлагыг Distributed Denial of Service гэж нэрлэдэг.

Өмнөх ижил төрлийн судалгаануудтай харьцуулахад, энэхүү ажлын гол онцлог нь өмнө нь өргөн хүрээнд туршигдаж байгаагүй, харьцангуй шинэ орчин болон тохиргоо бүхий систем дээр туршилтыг гүйцэтгэсэн явдал юм. Ихэнх судалгаанд уламжлалт эсвэл өргөн хэрэглэгддэг халдлага илрүүлэх системүүдийг стандарт орчинд туршсан байдаг бол энэхүү судалгаа нь Suricata системийн бодит хэрэглээний боломжийг өөр өнцгөөс үнэлсэнээрээ шинэлэг ач холбогдолтой гэж үзэж байна. Иймд уг үр дүн нь сүлжээний халдлага илрүүлэх системүүдийн судалгаанд шинэ нотолгоо нэмж өгч байна.

Шинжлэх ухааны үүднээс авч үзвэл, энэхүү судалгаа нь нээлттэй эхийн халдлага илрүүлэх системийг туршилтын орчинд ашиглан, түүний илрүүлэх болон сэргийлэх чадварыг баталгаажуулсан бодит туршилтын үр дүнг санал болгож байна. Энэ нь цаашид ижил төрлийн системүүдийн гүйцэтгэлийг харьцуулан судлах, мөн халдлага илрүүлэх механизмын үр ашгийг дээшлүүлэх судалгаанд суурь мэдээлэл болж ашиглагдах боломжтой.

Практик хэрэглээний хувьд, судалгааны үр дүн нь байгууллага, байгууллагын сүлжээний администратор болон мэдээллийн аюулгүй байдлын мэргэжилтнүүдэд Suricata системийг сүлжээний халдлагаас хамгаалах хэрэгсэл болгон ашиглах бодит боломж байгааг харуулж байна. Ялангуяа нээлттэй эхийн систем ашигласнаар зардал багатай, уян хатан шийдэл хэрэгжүүлэх боломжтой нь практик ач холбогдлыг нэмэгдүүлж байна.

Гэсэн хэдий ч энэхүү судалгаа нь зарим хязгаарлалттай. Тухайлбал, туршилтад ашигласан халдлагын төрөл хязгаарлагдмал байсан бөгөөд туршилтыг зөвхөн нэг л халдлага илрүүлэх систем дээр гүйцэтгэсэн. Иймд ирээдүйн судалгаанд халдлагын төрөл, сценарийг өргөжүүлэх, мөн олон төрлийн халдлага илрүүлэх системүүдийн гүйцэтгэлийг харьцуулан судлах нь илүү бодитой, ерөнхий дүгнэлт гаргахад чухал ач холбогдолтой гэж үзэж байна.

VI. Дүгнэлт

Дэлхий дахины хэмжээнд кибер аюулгүй байдлыг хангах асуудал хурцаар тавигдаж байгаа өнөө үед байгууллагын болон хувийн сүлжээний аюулгүй байдлыг хамгаалах, халдлагаас урьдчилан сэргийлэх маш амар, хялбар шийдэл бол нээлттэй эхийн IDS/IPS шийдэл юм.

Хувь хүн болон албан байгууллагууд зардал гаргалгүй ашиглах, программ хангамжийн эх кодуудыг өөрсдөөө тохируулах, хөгжүүлэлт хийх, хамгаалалтын дүрмүүдийг зохиох боломжийг олгоно.

Уг халдлагын эсрэг системийг илүү хөгжүүлэн хэрэглэгчид ээлтэй (User-friendly) интерфэйстэй болгон ашиглах боломжтой.

Цаашид уг системүүдийг хиймэл оюунд суурилсан шинжилгээний аргуудтай хослуулж, халдлагын хэв шинжийг автоматаар таних, дүрмийн санг ухаалгаар шинэчлэх, бодит цагийн аналитик гүйцэтгэх боломжийг бүрдүүлснээр илрүүлэлт болон сэргийлэлтийн үр ашгийг нэмэгдүүлэх боломжтой. Мөн аюулгүй байдлыг хангахын тулд системийн тохиргоог байнга шинэчилж, дүрмийн санг тогтмол шалгаж, сүлжээний орчны онцлог, шинэ төрлийн халдлагад нийцүүлэн дасан зохицуулах шаардлагатай. Ийм арга хэмжээнүүдийг хэрэгжүүлснээр нээлттэй эхийн IDS/IPS системүүдийн үр ашиг, найдвартай байдал, бодит цагийн хамгаалалт илүү өндөр түвшинд хүрэх боломжтой.

Иймд нээлттэй эхийн IDS/IPS системүүд нь зардал багатай, уян хатан, практик хэрэглээнд тохиромжтой хамгаалалтын хэрэгсэл төдийгүй, хиймэл оюунд суурилсан шинжилгээ, тогтмол тохиргоо, аюулгүй байдлын арга хэмжээг хослуулснаар байгууллага болон хувь хүний сүлжээний аюулгүй байдлыг тогтвортой, үр ашигтай хамгаалахад хувь нэмэр оруулах боломжтой.

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Evaluating the influence of AI systems on memory, attention, and analytical skills

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***Abstract*— This study examines the influence of artificial intelligence (AI) technologies on key cognitive processes among university students and instructors. In the context of digital transformation in higher education, AI has become a significant factor affecting attention, memory, critical thinking, creativity, and problem-solving skills. A mixed-methods approach was employed based on survey data collected from 83 respondents. Quantitative results indicate that AI has the strongest positive impact on memory and problem-solving (mean rating M = 5.0), supporting rapid information access and knowledge structuring. A moderate positive effect was observed for attention and creativity (M = 4.0), although participants reported risks related to distraction and reduced originality of ideas. Critical thinking emerged as the most vulnerable cognitive domain (M = 3.0), reflecting a tendency to rely on automated responses rather than independent analysis. Overall, the findings highlight the importance of responsible integration of AI and the development of pedagogical strategies aimed at fostering analytical reasoning and digital literacy.**

Keywords—artificial intelligence, cognitive processes, attention, memory, critical thinking, creativity, problem-solving, digital literacy, educational technologies, higher education.

I. INTRODUCTION

The rapid development of artificial intelligence (AI) technologies has significantly transformed the ways in which information is perceived, processed, and applied within educational settings [13]. In recent years, AI has become an integral component of the learning process—from intelligent systems for data search and analysis to generative models capable of producing texts, images, and solutions to complex tasks. As the number of AI-powered tools increases, so does the scale of their influence on human cognitive activity, making it essential to conduct an in-depth scientific examination of these changes.

Cognitive processes—such as attention, memory, critical thinking, creativity, and problem-solving—constitute the foundation of both academic and professional performance. These processes define the quality of knowledge acquisition and shape educational outcomes. The integration of AI into daily learning practices has the potential to enhance certain cognitive abilities while simultaneously weakening others, thereby creating new pedagogical challenges. For instance, AI can facilitate the structuring of large volumes of information and support algorithmic thinking, but uncontrolled use may reduce analytical depth or encourage superficial learning strategies.

International studies highlight the dual nature of AI's impact on cognitive functioning. According to recent reports by UNESCO and the OECD (2023–2024), digital tools significantly increase access to knowledge and enable personalization of learning [8,9]. At the same time, they influence cognitive load, attention patterns, and student motivation. Whether AI fosters learner autonomy or, conversely, encourages dependence on ready-made algorithmic solutions remains an open question [10]. This uncertainty underscores the need for empirical assessments of AI's effects on cognitive components, particularly in higher technical education, where digital tools are used most intensively.

Despite growing academic interest in this topic, research on the influence of AI on cognitive processes among students in Central Asia remains limited. The educational environment of Uzbekistan has undergone rapid digital transformation in recent years, making the study of AI usage especially relevant. The local context is characterized by limited access to traditional resources, high motivation to master ICT, accelerated implementation of digital platforms, and a strong ability of students to adapt to new technological tools.

Therefore, the present study aims to evaluate how students and university instructors perceive the influence of AI on key cognitive processes and what specific changes they observe in their learning practices. The findings help identify the advantages, limitations, and potential risks associated with AI use, providing a basis for developing recommendations for its safe and effective integration into educational activities.

II. LITERATURE REVIEW

The question of how artificial intelligence influences human cognitive functions has become a central topic in contemporary academic discourse. Over recent years, numerous studies have examined the transformation of attention, memory, and reasoning mechanisms under the impact of digital tools, including generative models and adaptive learning systems.

Modern researchers emphasize that AI is increasingly capable of replicating elements of human cognition, such as logical reasoning, information generalization, and learning from accumulated experience [1,2,15]. Many international

authors describe generative AI models as "cognitive partners" that augment human thinking, particularly in tasks involving data analysis, creativity, and complex problem-solving.

Another significant body of research addresses the ethical and psychological implications of AI integration. Lyapuntsova and Vlasova [2] argue that AI's interaction with human cognition inevitably raises concerns about intellectual autonomy, accuracy of knowledge, and the quality of decision-making. Scholars highlight the importance of interdisciplinary approaches linking cognitive psychology, neuroscience, and computer science.

Several studies focus on the risks associated with excessive reliance on digital technologies. The "lazy brain paradox" suggests that constant dependence on AI may reduce analytical depth and autonomy, fostering a tendency toward superficial information processing [3,4]. These effects are particularly notable among university students, who frequently use AI to accelerate assignments, potentially leading to reduced cognitive load and weaker critical thinking skills. Generative AI models are described as cognitive partners that augment human thinking and support complex problem-solving. [5, 6]

International reports from UNESCO and the OECD (2023–2024) reinforce the dual nature of AI's impact on cognition:

on the one hand, AI enhances personalized learning, reduces cognitive load, and improves access to information;

on the other hand, it may alter attention patterns, reduce sustained concentration, and encourage habitual reliance on quick algorithmic responses [8, 9].

Despite the growing number of studies in this field, there is still a lack of research examining the cognitive effects of AI on learners in Central Asia. Given the rapid digital transformation in Uzbekistan's education system, this topic is highly relevant, as the integration of AI requires a careful assessment of its consequences for the cognitive development of students in technical disciplines.

Overall, the literature demonstrates that AI exerts a dual influence: it expands cognitive capabilities while simultaneously introducing risks that require pedagogical oversight. These findings highlight the need for empirical studies aimed at identifying which aspects of cognition are strengthened by AI and which may require additional support within the educational process.

III. RESEARCH DESIGN

The study was conducted at the Tashkent University of Information Technologies named after Muhammad al-Khwarizmi and was aimed at examining the influence of artificial intelligence technologies on key cognitive processes among students and university instructors. The methodological framework of this study was based on a mixed-methods approach combining quantitative and qualitative strategies [3].

Ethical considerations were carefully addressed throughout the research process. All participants were informed about the purpose of the study, the voluntary nature of participation, and their right to withdraw at any stage without any adverse consequences. Informed consent was obtained prior to data collection. The study protocol was approved at the institutional level by the Tashkent University of Information Technologies named after Muhammad al-Khwarizmi. Data were collected and analyzed in an anonymized form, with no personally identifiable information recorded. Access to the dataset was restricted to the research team, and the data were used exclusively for academic purposes in accordance with institutional data protection policies

Participants

A total of 83 respondents participated in the study, including:

- 18 instructors
- 65 students.

Gender distribution:

- 24 female
- 59 male participants.

Inclusion criteria were as follows:

1. active use of AI technologies for at least one month;
2. voluntary participation;
3. understanding of the study's objectives and data processing procedures.

This composition allowed for cross-group comparisons and identification of specific perceptual patterns.

Instruments

Data were collected using a structured questionnaire consisting of two main sections: a quantitative and a qualitative block.

1. Quantitative section

The first part included a series of statements assessed on a five-point Likert scale (1 — "no influence", 5 — "strong influence"). Participants evaluated how AI affects the following cognitive processes:

- attention,
- memory,
- critical thinking,
- creativity,
- problem-solving.

Sample items:

- Does AI help you maintain concentration while completing tasks?
- Does AI enhance your ability to memorize or recall information?
- Does AI influence your capacity for independent analytical thinking?

This scale enabled a systematic quantitative assessment of participants' perceptions.

2. Qualitative section

The second part invited respondents to provide open-ended reflections on their experiences using AI. Questions focused on:

- specific examples of AI use;
- perceived advantages and limitations;
- observed cognitive changes;
- user concerns and expectations.

Responses were interpreted through thematic coding, with the following categories emerging: "cognitive enhancement," "risks and challenges," "changes in learning strategies," and "impact on motivation."

Procedure

- The survey was administered online using a secure Google Forms platform.
- Completion time averaged 7–10 minutes.
- Participants were informed in advance about anonymity and confidentiality.
- Data were processed using Excel and SPSS (descriptive statistics: means, medians; group comparisons by mean values).
- Invalid or incomplete responses were removed during data cleaning.

Internal consistency was assessed using Cronbach's Alpha, which showed a high level of reliability ($\alpha = 0.84$). Validity was ensured through expert evaluation and pilot testing on a small sample.

The study adhered to ethical standards of voluntary participation and confidentiality. All respondents provided informed consent, and the data were analyzed in anonymized form.

IV. Results

The analysis revealed that AI exerts the strongest positive influence on memory and problem-solving. [11] The quantitative results, summarized in Table 1, illustrate the overall tendencies reported by the participants.

TABLE I. Descriptive statistics of AI impact on cognitive processes (Mean ± SD)

Cognitive process	Mean score	SD
Memory	5.0	< 0.10
Problem-solving	5.0	< 0.10
Attention	4.0	0.78
Creativity	4.0	0.81
Critical thinking	3.0	0.92

A. Memory and problem-solving

Memory and problem-solving received the highest mean ratings ($M = 5.00$, $SD < 0.10$), indicating strong consensus among participants regarding the positive role of AI in these cognitive domains. Respondents emphasized that AI accelerates information retrieval, supports the structuring of learning materials, facilitates algorithmic thinking, and assists in data analysis for academic assignments. The very low variability suggests a consistent perception of AI as an effective cognitive support tool in task execution and analytical activities.

B. Attention

Attention demonstrated a moderately positive effect ($M = 4.00$, $SD = 0.78$). Participants reported advantages such as reduced cognitive load and faster access to relevant information. At the same time, several limitations were noted, including excessive notifications, multitasking demands, and occasional overreliance on AI-generated suggestions, which may negatively affect sustained focus.

C. Creativity

Creativity was also rated positively ($M = 4.00$, $SD = 0.81$). Respondents highlighted AI's role in idea generation and inspiration, particularly during the initial stages of creative tasks. However, concerns were expressed regarding potential loss of originality and the production of template-like outputs, indicating a need for balanced use of AI in creative activities.

D. Critical Thinking

Critical thinking received the lowest mean score ($M = 3.00$, $SD = 0.92$), reflecting substantial variability in responses and heightened concern among participants. Respondents reported risks associated with uncritical acceptance of AI-generated answers, reduced analytical engagement, and the development of cognitive dependence. These findings align with previous research addressing the phenomenon of "passive thinking" in technology-supported learning environments [10].

E. Differences between students and instructors:

Descriptive comparisons revealed notable differences between participant groups. Students more frequently indicated reduced motivation and oversimplification of learning tasks when using AI tools, whereas instructors emphasized improved efficiency in planning, analysis, and assessment activities. Gender-based patterns suggested that female participants more often highlighted creative enhancement, while male participants emphasized analytical and technical benefits associated with AI use

V. Limitations of the Study

Despite the contributions of this study, several limitations should be acknowledged when interpreting the findings.

First, the sample was drawn from a single higher education institution, which limits the generalizability of the results to broader educational contexts. The findings therefore reflect the characteristics of a specific institutional environment and the digital readiness of its participants.

Second, the study relied on self-reported data, with participants evaluating the perceived impact of artificial intelligence on their own cognitive processes. This approach may be subject to response biases, including social desirability effects and limited self-awareness. The inclusion of objective cognitive measures would strengthen the validity of future research.

Third, the sample size ($N = 83$) restricts the use of more advanced statistical modeling and the detection of subtle group differences. In addition, the cross-sectional design of

the study does not allow for assessment of long-term cognitive changes associated with sustained AI use.

Future studies should therefore consider larger and more diverse samples, involve multiple institutions, adopt longitudinal research designs, and integrate objective and behavioral assessments to obtain a deeper understanding of the cognitive effects of artificial intelligence.

Conclusion

The present study provides a comprehensive assessment of how artificial intelligence technologies influence key cognitive processes among university students and instructors. The findings demonstrate that AI exerts a multifaceted and ambivalent impact on cognitive processes [12]. Its effects depend on the purposes of use, user competencies, and the educational context.

AI showed the strongest positive influence on memory and problem-solving, functioning as a tool for rapid information retrieval, knowledge structuring, and generating efficient solutions. These results align with international research emphasizing AI's potential to reduce cognitive load and enhance analytical performance [11, 7].

A moderate positive effect was observed on attention and creativity, with participants noting improved focus and increased capacity for idea generation. However, challenges were also identified, including distraction caused by multitasking with digital tools and the tendency of generative models to produce template-like content [5, 6].

The most vulnerable area proved to be critical thinking, where participants reported reduced independence, shallower analysis, and a tendency to rely on ready-made responses. This pattern corresponds with the concept of "passive thinking," which emerges when digital prompts replace active cognitive engagement [10]. The findings highlight the need for pedagogical strategies aimed at promoting analytical reasoning and argumentation skills [3].

Overall, AI can serve as an effective educational tool, but only when used responsibly and thoughtfully. To ensure its safe and productive integration, the following recommendations are proposed:

1. Integrate AI in ways that prioritize the development of critical thinking rather than merely accelerating task completion.
2. Design learning activities requiring verification, analysis, and comparison of AI-generated outputs.
3. Improve students' digital literacy by teaching them to evaluate the accuracy, validity, and ethical implications of AI use.
4. Implement specialized AI literacy courses that foster conscious and independent application of digital tools.
5. Maintain a balance between manual cognitive efforts and automated assistance to prevent algorithmic dependency.

In conclusion, AI has the potential to enhance personalization and efficiency within higher education. However, its meaningful use requires strengthening metacognitive skills and fostering critical awareness among learners. The results of this research provide a foundation for further studies exploring the long-term cognitive effects of AI, the effectiveness of blended learning approaches, and the development of pedagogical models that incorporate AI without compromising the quality of human reasoning.

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Online learning and motivation: a self-determination theory approach

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***Abstract*— The article examines the impact of key factors from Self-Determination Theory (SDT) on student motivation in the context of online learning. The focus is on the satisfaction of psychological needs for autonomy, competence, and relatedness, as well as their relationship with intrinsic and extrinsic motivation. Based on data collected from 372 students, significant correlations between these variables were identified. In particular, autonomy demonstrated the strongest association with motivation (r = 0.686), while competence (r = 0.520) and relatedness (r = 0.479) showed moderate relationships. The article concludes with recommendations for enhancing student motivation, including fostering flexibility in learning, strengthening feedback, and improving social interactions in the online environment.**

Keywords*—autonomy, competence, digital education, intrinsic and extrinsic motivation, online learning, relatedness, Self-Determination Theory (SDT), student motivation.

I. Introduction

In March 2020, the COVID-19 pandemic forced universities and colleges worldwide to switch to online learning. This abrupt transition, driven by lockdowns, affected all spheres of public life. During the initial months, educational institutions faced challenges related to technical preparation, organization of the learning process, and the psychological adaptation of students and teachers [2]. However, over the past four years, the initial shock has been replaced by a phase of analysis and reflection on the consequences of this transition [2].

Numerous studies have been devoted to the impact of online learning on various aspects of the educational process, including academic performance, the specifics of interaction between students and teachers, the emotional state of learners, as well as emerging organizational and technical difficulties [3]. At the same time, the issue of student motivation remains one of the keys and most complex topics. The pandemic has demonstrated the diversity of online learning formats, encompassing synchronous sessions in real-time (e.g., via Zoom or Microsoft Teams) and asynchronous formats based on materials from massive open online course (MOOC) platforms. Although such tools have significantly expanded access to education, the very format of distance learning has sparked debates about its quality and effectiveness.

Several perspectives are highlighted regarding the effectiveness and quality of distance education:

- Online learning can achieve a level of quality comparable to traditional in-person education [4-6].
- At present, online learning does not meet the quality criteria of the traditional format, but this may become possible in the future [7].
- Distance education will inevitably fall short of in-person learning because of inherent limitations that cannot be fully overcome [8].

One of the most debated issues in online learning remains student motivation. The complexity of motivation as a phenomenon is due to several factors: on the one hand, it is interconnected with the subject's needs and will, and on the other, it cannot be unequivocally defined within the frameworks of biological, psychological, or sociocultural perspectives [9,10]. The relationship between motivation and academic success is considered important by most researchers, while the understanding of motivation and its nature remains a subject of debate in the academic community. Academic researchers in online education have focused their efforts on exploring the relationships between motivation and other variables: course structure, learning organization, specifics of the learning environment, autonomy, gender characteristics, professional employment, levels of aspiration, instructor competence, types of rewards, communicativeness, anxiety, media literacy, and other aspects [11]. Currently, there are several main approaches to understanding motivation. Among the most developed are the attribution theory (establishing cause-and-effect relationships to explain performance outcomes), expectancy theory (motivation as a function of success expectations), goal orientation theory (achieving results or avoiding failures), social-cognitive theory (autonomy as the main driving force of motivated actions), and self-determination theory (SDT). SDT highlights three key psychological needs, the satisfaction of which contributes to the enhancement of intrinsic motivation:

Autonomy — the ability of students to choose and control their educational process.

Competence — confidence in their ability to cope with academic tasks.

Relatedness - a sense of belonging to the student and faculty community.

Self-Determination Theory (SDT), developed by R. Ryan and E. Deci, provides a conceptual framework for analyzing intrinsic and extrinsic motivation, which we apply in this article to study the impact of key educational process factors on student motivation. In particular, SDT will allow us to evaluate how satisfying the needs for autonomy, competence, and relatedness contributes to improving students' engagement and academic success in online learning conditions, as well as their impact on educational outcomes.

The purpose of this article is to examine the impact of key factors identified by Self-Determination Theory on student motivation in the context of online learning. The authors aim to determine how the satisfaction of autonomy, competence, and relatedness needs influences intrinsic and extrinsic motivation, as well as to provide recommendations for improving the educational process.

II. MATERIALS AND METHODS

The research sample comprised 372 undergraduate students aged 19 to 28 years, enrolled at the Tashkent University of Information Technologies (TUIT) named after Muhammad al-Khorazmi and its three regional branches. Participation in the study was entirely voluntary, and all data were collected anonymously to ensure confidentiality.

A. Survey methodology

The study employed a structured questionnaire incorporating two psychometric scales to assess key variables:

1. Basic Psychological Needs Scale (BPNS) This scale was utilized to evaluate the degree of fulfillment of three fundamental psychological needs: autonomy, competence, and relatedness. Sample items:

1. *Autonomy: "I feel that I can make my own choices about how and when I learn."*
2. *Competence: "I feel confident that I can handle learning tasks."*
3. *Relatedness: "I feel part of a learning community."*

Responses were recorded using a 7-point Likert scale ranging from 1 (completely disagree) to 7 (completely agree).

2. Academic Motivation Scale (AMS) This scale was implemented to measure intrinsic and extrinsic dimensions of academic motivation.

Sample items:

1. *Intrinsic motivation: "I study a subject because it is interesting."*
2. *Extrinsic motivation: "I study to get a high grade."*

This methodological approach facilitated a comprehensive analysis of students' psychological needs and motivational orientations.

The questionnaire consisted of 15 questions and was distributed through the Google Forms platform. The time to fill out the questionnaire was 10-15 minutes.

B. Data collection

Data collection was carried out over a one-month period in 2024 using an online survey platform. Prior to participation, all respondents provided informed consent, ensuring their voluntary engagement in the study and adherence to ethical research standards.

C. Data analysis

The following methods were employed for data processing and analysis:

Descriptive statistics. Mean values and standard deviations were calculated for each variable: autonomy, competence, relatedness, and overall motivation. These metrics provided an overview of the current level of satisfaction with basic needs and student motivation.

Correlation analysis. Pearson's correlation analysis was used to evaluate the relationships between the variables of autonomy, competence, relatedness, and overall motivation. This allowed for identifying which variables were most strongly associated with each other.

Regression analysis. Regression analysis was employed to determine the contribution of each variable (autonomy, competence, relatedness) to students' overall motivation.

The formula for calculating mean values for each variable (autonomy A, competence C, relatedness R) was as follows:

$$\bar{X} = \frac{\sum_{i=1}^{n} x_i}{n} \quad (1)$$

where:

x_i — the value of the variable for the i-th student,

n — the total number of students (372)

Example calculation for autonomy:

$$\bar{A} = \frac{\sum_{i=1}^{372} A_i}{372}$$

The autonomy values were summed up $\sum \mathrm{A_i} = 1678.92$ and divided by the total number of students $n = 372$

As a result, we obtained the mean autonomy value.

$$\overline{\mathrm{A}} = \frac{1678.92}{372} = 4.51$$

Similarly, the mean values for the other variables were calculated: $\bar{C} = 4.17, \bar{R} = 4.12, \bar{M} = 4.29$

The formula for standard deviation:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{X})^2}{n}} \quad (2)$$

where:

x_i — the value of the variable for the i-th student, $\bar{X}$ — mean value of the variable, n — number of students.

Example calculation for autonomy:

$$\sigma_A = \sqrt{\frac{\sum_{i=1}^{372}(A_i - \bar{A})^2}{372}}$$

The sum of squared deviations for autonomy was 235.68, hence:

$$\sigma_A = \sqrt{\frac{235.68}{372}} = 0.80$$

Similarly, the mean values for the other variables were calculated: $\sigma_C = 0.70,\ \sigma_R = 0.90,\ \sigma_M = 0.75$

To identify the relationships between the variables of autonomy (A), competence (C), relatedness (R), and motivation (M), Pearson's correlation coefficient (r) was used:

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \bar{X})(y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{X})^2 \cdot \sum_{i=1}^{n}(y_i - \bar{Y})^2}} \quad (3)$$

where: x_i, y_i — the values of two variables for the i-th student, $\bar{X}, \bar{Y}$— their mean values.

Example of the correlation between autonomy and motivation:

$$r_{AM} = \frac{\sum_{i=1}^{372}(A_i - \bar{A})(M_i - \bar{M})}{\sqrt{\sum_{i=1}^{372}(A_i - \bar{A})^2 \cdot \sum_{i=1}^{372}(M_i - \bar{M})^2}}$$

The calculations yielded $r_{AM} = 0.686$

Similar values for the other pairs were: $r_{CM} = 0.520$, $r_{RM} = 0.479$

To evaluate the contribution of autonomy (A), competence (C), and relatedness (R) to overall motivation (M), the following model was used:

$$M = w_1 \cdot A + w_2 \cdot C + w_3 \cdot R + \epsilon \quad (4)$$

where: $w_1 = 0.4, w_2 = 0.35, w_3 = 0.25$ — weights of the variables, ϵ — the random error of the model.

Example calculation of overall motivation for one student:

$$M_i = 0.4 \cdot A_i + 0.35 \cdot C_i + 0.25 \cdot R_i$$

for student with $(A_i = 4.8), (C_i = 4.2), (R_i = 4.0)$

$$M_i = 0.4 \cdot 4.8 + 0.35 \cdot 4.2 + 0.25 \cdot 4.0 = 4.39$$

The mean motivation value was calculated across all students: $\bar{M} = 4.29$

III. Results

The results are presented in the following table:

TABLE I. Summary of variables and their relationship with motivation

Variable	Mean (M)	Standard deviation (SD)	Correlation with motivation (r)
Autonomy (A)	4.51	0.80	0.686
Competence (C)	4.17	0.70	0.520
Relatedness (R)	4.12	0.90	0.479
Motivation (M)	4.29	0.75	1.000

The findings of the study demonstrate that students generally perceive their levels of autonomy, competence, relatedness, and overall motivation as above average. Autonomy, with a mean score of 4.51 and a substantial positive correlation with motivation (r = 0.686), was identified as the most critical determinant of students' overall motivation. This underscores the pivotal role of fostering autonomy in educational contexts, emphasizing the need to empower students by granting them greater agency in making decisions about their learning processes, including the selection of task formats and the determination of assignment deadlines.

Competence, with a mean score of 4.17 and a moderate positive correlation with motivation (r = 0.520), also emerged as a significant factor in sustaining motivation. The moderate mean value indicates that while students exhibit a reasonable level of confidence in their abilities, there is potential for enhancement. Strategies such as providing consistent, constructive feedback and ensuring access to supplementary learning resources could further strengthen their sense of competence.

Relatedness, with a mean score of 4.12 and the lowest correlation with motivation (r = 0.479) among the three factors, was found to be the least influential variable in predicting motivation. Nonetheless, its role should not be underestimated, as fostering a sense of connection and belonging remains a vital component of a holistic approach to motivation enhancement.

This indicates that students experience insufficient connection with instructors and peers in the context of online learning. Despite the lower correlation, this variable still influences motivation and requires improvement through fostering social interactions in the educational environment.

Students' overall motivation has a mean value of 4.29, suggesting that students are generally motivated in online learning conditions, though there is significant room for improvement. Enhancing autonomy and competence, as well as fostering a sense of relatedness, will help achieve a higher level of engagement and academic success.

Based on the results, we have developed the following recommendations to increase student motivation. To improve motivation in online learning, it is essential to address the satisfaction of all three basic psychological needs: autonomy, competence, and relatedness.

1) To foster greater learner autonomy, it is imperative to grant students increased agency in managing their educational trajectories. This encompasses allowing them to select preferred formats for task completion—such as essays, presentations, or projects—providing flexibility in deadline management, and offering the opportunity to explore supplementary topics of interest. For instance, the integration of project-based learning methodologies can empower students to independently choose tasks and devise personalized problem-solving strategies. Enhancing autonomy not only augments intrinsic motivation but also cultivates critical decision-making competencies, thereby aligning with the principles of self-determination theory and experiential learning frameworks.

2) To enhance students' self-efficacy, it is essential to equip them with appropriate tools and support mechanisms. This can include providing regular, constructive, and detailed feedback on their performance to guide improvement. Additionally, offering structured, step-by-step instructions for complex tasks and incorporating brief practical exercises or formative assessments enables students to evaluate their understanding before engaging with more challenging assignments. These measures reinforce a sense of competence, which, according to self-determination theory, significantly contributes to increased motivation and improved academic outcomes.

3) To foster a stronger sense of relatedness, it is essential to enhance the quality of social interactions between students and instructors. This objective can be achieved through the integration of collaborative activities such as group projects, virtual discussions, and informal networking opportunities. For example, organizing weekly virtual "coffee chats" or team-based quizzes can facilitate a greater sense of belonging within the learning community. Moreover, fostering an environment of openness and approachability among instructors is critical, as it enables students to seek guidance and support when needed. These measures are particularly effective in mitigating the feelings of isolation commonly associated with online learning contexts.

4) To enhance overall student motivation, educators should design courses that simultaneously promote intellectual growth, foster a supportive environment, and offer challenges aligned with students' competency levels. The integration of gamification strategies—such as leaderboards, achievement badges, and optional bonus assignments—can significantly increase engagement and drive motivation. A critical factor in this approach is achieving an optimal balance between challenge and support to prevent disengagement caused by boredom or undue cognitive overload.

IV. Limitations

This study has limitations that should be considered when interpreting the findings. The sample was limited to students from a single university and its regional branches, which may restrict the generalizability of the results. In addition, self-report questionnaires may introduce response bias. Data collection was conducted online, limiting control over survey conditions. Future studies could expand the sample and apply mixed research methods

V. Conclusion

The shift to online learning prompted by the COVID-19 pandemic has underscored the critical importance of investigating student motivation within the digital education landscape. This article explores the fundamental psychological needs of autonomy, competence, and relatedness, as outlined by Self-Determination Theory (SDT), which are pivotal for sustaining motivation. The findings demonstrate that fostering conditions that satisfy these needs enhances student engagement and academic achievement. Key recommendations include providing students with greater autonomy in selecting educational activities, delivering consistent and constructive feedback, and facilitating meaningful interactions within the learning community. These strategies can guide educators and academic administrators in redesigning educational programs to meet the unique challenges of the online environment, thereby making them more effective and student-centered. Looking forward, it is imperative to establish robust criteria for selecting participants in quantitative and qualitative research and to direct significant attention to studies grounded in SDT. This framework remains one of the most heuristic approaches due to its explanatory power, predictive capabilities, and practical applicability. Additionally, it would be valuable to conduct studies dedicated to cross-comparisons of motivation assessments between instructors and students, as well as to adapt theories and methodologies for online learning in higher education.

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Fundamental Research on Soil Heaving and Freezing Depth in Cold Regions

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Abstract— This study investigates the seasonal soil heave and freezing depth characteristics in the cold climatic conditions of Mongolia, focusing on the experimental site located within the premises of Mongol Koosen Technology College. The research aims to obtain continuous field data on soil frost heave, ground temperature variation, groundwater level changes, and freezing index values in order to better understand soil deformation processes and their engineering implications. A combination of geodetic leveling measurements, subsurface temperature sensors installed at various depths (0.1–5 m), groundwater level and temperature monitoring, grain-size analysis, natural moisture determination, and laboratory density tests were conducted. Additionally, freezing indices for the past ten years were calculated using 2-point, 8-point, 12-point, and 24-point air-temperature methods to compare the annual severity of freezing conditions.

The results indicate that seasonal frost heave began developing from mid-November, with maximum upward displacement reaching 7 mm during the coldest period. Ground temperature measurements show that shallow layers (0.1–0.5 m) respond strongly to atmospheric temperature fluctuations, transitioning to subzero values in winter, while deeper layers (3–5 m) remained thermally stable. The freezing depth was determined to reach approximately 1.6 m from the ground surface. Groundwater temperature decreased with depth, consistent with permafrost-influenced conditions. Soil analysis shows a gravelly–sandy texture with minimal clay content, suggesting low moisture retention and a relatively lower susceptibility to frost heave compared to fine-grained soils.

Overall, the collected data provide an essential basis for predicting soil deformation processes in cold regions and for improving engineering design considerations for foundations, roads, and infrastructure constructed on seasonally freezing soils in Mongolia.

Keywords—frost heave, seasonal freezing depth, ground temperature, freezing index, ground water fluctuations

I. INTRODUCTION

Cold climate regions such as Mongolia experience significant engineering challenges due to seasonal soil freezing and thawing processes. During winter, the penetration of low temperatures into the ground leads to frost heave, while the subsequent thawing during warmer months results in soil settlement. These cyclic deformations can cause substantial damage to infrastructure, including foundations, pavements, and embankments. Understanding the mechanisms and extent of these soil changes is therefore essential for designing durable structures in cold environments.

Previous studies in Mongolia and other cold regions have emphasized the influence of soil type, groundwater conditions, climatic severity, and thermal regimes on frost-related deformation. However, long-term, site-specific monitoring data remain limited, particularly for urban and semi-urban areas where infrastructure development is rapidly increasing. Reliable field data are crucial for improving predictive models and establishing engineering design parameters such as frost heave potential, freezing depth, and freezing index.

To address this gap, the present study conducts comprehensive field measurements at the Mongol Koosen Technology College research site. The investigation focuses on monitoring soil heave, ground temperature variation at multiple depths, groundwater level and temperature changes, and calculating the freezing index using various temperature-based methods. Laboratory analyses, including grain-size distribution, natural moisture content, and particle density tests, complement the field data to characterize the soil's physical properties.

By integrating long-term environmental observations with laboratory soil characterization, this research aims to provide fundamental insights into soil behavior under freezing conditions in Mongolia. The findings contribute to improved engineering assessments, enabling more accurate predictions of seasonal soil deformation and supporting the development of resilient infrastructure in cold regions.

II. LITERATURE REVIEW

A. International Studies on Frost Heave and Freezing Depth

Soil freezing and frost heave have been extensively studied in cold and permafrost regions due to their significant impact on infrastructure performance (Dashjamts, 2019). Early theoretical foundations were established by researchers, who identified ice lens formation and water migration as the primary mechanisms responsible for frost heave in fine-grained soils. Later studies by Miller (1972) and Konrad and Morgenstern (1980) further refined the understanding of thermodynamic and hydraulic processes governing ice segregation under freezing conditions.

In North America and Northern Europe, numerous experimental and analytical investigations have focused on the relationship between soil type, moisture availability, freezing rate, and frost susceptibility. Andersland and Ladanyi (2004) summarized that silts and silty sands exhibit the highest frost heave potential, while coarse-grained soils with low fines content are generally less susceptible, consistent with soil mechanics principles described by Dashjamts (2019). Field monitoring studies conducted in Canada, Sweden, and Finland demonstrated that seasonal freezing depth is strongly correlated with the freezing index, snow cover thickness, and soil thermal properties, a concept also applied in Mongolia using national meteorological datasets (National Agency for Meteorology and Environmental Monitoring, 2024)

Recent studies have increasingly relied on numerical modeling and long-term field instrumentation. Researchers have applied coupled heat–moisture transfer models to predict frost penetration depth and heave magnitude under changing climatic conditions (Hansson et al., 2004; Zhou et al., 2018). These studies highlight that climate warming may reduce freezing depth in some regions, while increased temperature variability can intensify freeze–thaw cycles, leading to higher risks of pavement and foundation damage.

B. Research in Permafrost Regions

In permafrost-dominated regions such as Siberia, Alaska, and the Tibetan Plateau, studies emphasize the interaction between seasonal frost and underlying permafrost layers. Tsytovich (1975) and Yershov (1998) reported that permafrost acts as a thermal barrier, limiting geothermal heat flow and stabilizing deeper ground temperatures. Field observations confirm that groundwater temperature often decreases with depth in continuous permafrost zones, contrasting with conditions in non-permafrost areas.

Engineering-focused research in these regions has addressed frost-related deformation of foundations, embankments, and pipelines. Mitigation measures such as thermal insulation layers, ventilated embankments, and non-frost-susceptible materials have been widely studied and implemented (Doré & Zubeck, 2009). These findings provide valuable references for countries like Mongolia, where permafrost and seasonally frozen ground coexist.

III. METHODOLOGY

A. Measuring Frost Heave by Geodetic Surveying

In this measurement, the elevation of one fixed reference point and three measurement points within the premises of “Mongol Kosen” Technology College were recorded. The elevation differences between the fixed point and the three variable points were measured weekly using a leveling instrument, and the data were used to generate graphs illustrating frost heave behavior.

B. Groundwater Level and Temperature Measurement

The groundwater level was measured using a hand-made device lowered into a 16-meter-deep PVC borehole created by rotary drilling. A weight and float were inserted into the borehole; when the float contacted the water surface, the string was gently pulled upward. The depth to the water surface was determined by measuring the distance between the marked string point at the borehole rim and the attachment point of the float.

Groundwater temperature was measured by lowering a temperature sensor into the same 16-meter borehole at depths of 5 m, 8 m, 10 m, and 15 m. A thermometer was connected to the sensor to record temperature readings at each depth.

C. Sensors Installed in Soil Layers

Three boreholes were equipped with temperature sensors at the following intervals:

- Borehole 1: Sensors placed at 10 cm intervals from 0.1 m to 1 m
- Borehole 2: Sensors placed at 50 cm intervals from 0.5 m to 2.5 m
- Borehole 3: Sensors placed at 50 cm intervals from 0.5 m to 5 m

These sensors continuously recorded temperature variations at different soil depths.

D. Freezing Index

The freezing index represents the severity and depth of seasonal frost penetration. It is determined based on accumulated negative air temperatures and is widely used to estimate frost depth and evaluate frost-related risks. Using the 10-year air temperature dataset (2015–2025) obtained from the National Agency for Meteorology and Environmental Monitoring, the freezing index was calculated using the following methods:

- 2-point method: Sum of the daily maximum and minimum temperatures
- 8-point method: Sum of air temperatures recorded every 3 hours
- 12-point method: Sum of air temperatures recorded every 2 hours
- 24-point method: Sum of hourly air temperatures

These methods allow comparison of freezing severity across different years and climatic conditions.

IV. RESULTS AND DISCUSSION

This section presents the results obtained from field measurements, sensor data, laboratory analyses, and freezing index calculations, followed by an integrated discussion of their implications. The findings provide insight into the seasonal thermal behavior of the soil, the extent of frost penetration, and the mechanical response of the ground under cold-climate conditions. By comparing multiple datasets—such as soil temperature profiles, groundwater characteristics, frost heave measurements, and particle size distribution—this section aims to explain the interactions between climatic factors and soil processes within the study area.

A. Determination of Frost Heave by Geodetic Measurement

Weekly leveling surveys conducted from August 19, 2024, to April 2025 show the elevation changes of the three measurement points relative to the fixed benchmark. The results indicate that soil surface deformation corresponds closely with seasonal temperature variation. Notably, frost heave increased significantly during January, reaching up to 7 mm, while subsidence occurred during periods of high rainfall in August, reaching –4 mm.

These magnitudes fall within the allowable tolerance specified in the Mongolian construction standard BNbD 2.02.01-94, which permits elevation deviations of up to ±10 mm. This confirms that the observed heave and settlement are within natural seasonal limits.

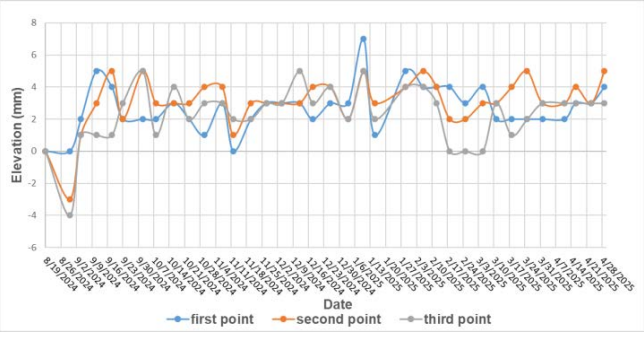


Fig. 1.Ground elevation comparison

B. Groundwater Level

Groundwater levels showed fluctuations but did not demonstrate a clear correlation with soil heave or temperature. Seasonal precipitation and infiltration patterns are likely influencing the observed variability. Due to multiple contributing factors, including soil permeability, rainfall, and evaporation rates, the current data are insufficient to form a definitive cause-effect relationship. Additional long-term monitoring and hydrological modeling would be required for stronger interpretation.

C. Groundwater Temperature

Temperature measurements indicate that groundwater becomes colder with increasing depth, which is consistent with the influence of continuous permafrost in Mongolia. Unlike non-permafrost regions where groundwater typically becomes warmer at depth, the permafrost layer restricts heat transfer and prevents geothermal warming. The results confirm that the deeper groundwater temperature remains stable throughout the year, indicating minimal influence from atmospheric temperature changes.

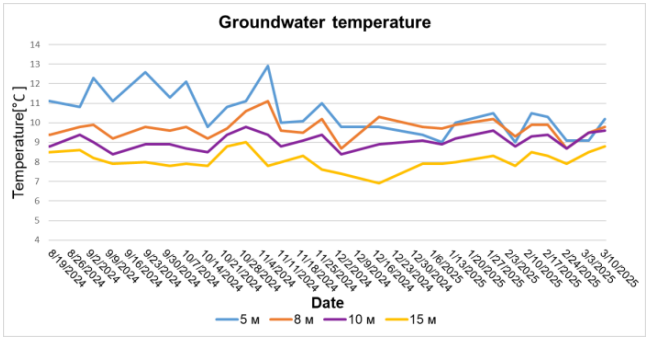


Fig. 2. Groundwater temperature

D. Soil Temperature

Temperature sensors installed in the boreholes recorded significant differences between shallow and deep soil layers:

- Soil layers at 0.1 m to 0.5 m responded rapidly to atmospheric cooling, reaching subzero temperatures in early winter.
- At depths greater than 3 m to 5 m, seasonal temperature change was minimal or nonexistent.
- The maximum seasonal frost penetration reached approximately 1.6 m.

This demonstrates that temperature effects weaken with depth, and the lower soil layers remain thermally stable, confirming the presence of a permafrost-influenced thermal regime.

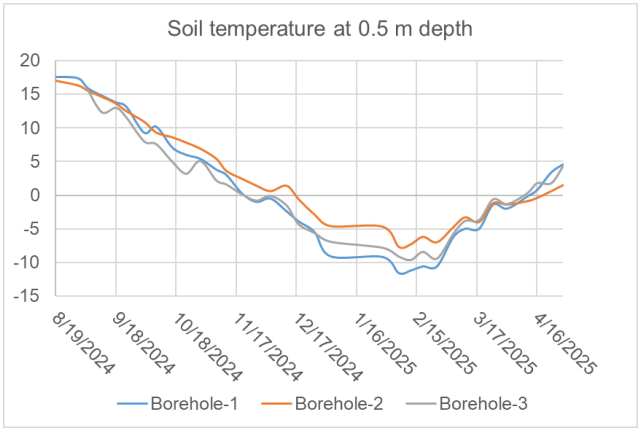


Fig. 3. Soil temperature

V. CONCLUSION

This study investigated seasonal frost heave, soil temperature variation, groundwater characteristics, and soil properties within the premises of "Mongol Kosen" Technology College. The results provide a comprehensive understanding of the thermal and mechanical behavior of the soil under cold-climate conditions.

The monitoring data confirmed that soil frost heave and settlement occur naturally with seasonal temperature changes, with a maximum heave of 7 mm in winter and a settlement of –4 mm during periods of high rainfall. These deformations fall within the allowable limits specified by national construction standards, indicating that the observed ground movements do not pose immediate structural risks.

Soil temperature measurements demonstrated that shallow soil layers react quickly to atmospheric temperature, while deeper layers remain thermally stable. The maximum frost penetration depth reached approximately 1.6 m, consistent with the influence of continuous permafrost in Mongolia. Groundwater temperature remained nearly constant throughout the year and decreased with depth, further supporting the presence of a permafrost-controlled thermal regime.

The freezing index calculated using 10 years of temperature data showed notable annual variation. Among the calculation methods used, the 8-point and 12-point methods produced the most accurate and consistent results. The winter of 2023–2024 exhibited the highest freezing index, confirming it as the coldest winter in recent years.

Overall, the study provides essential baseline information for engineering design, construction planning, and infrastructure maintenance in cold regions. The findings contribute to a better understanding of frost-related ground behavior and support the development of appropriate mitigation strategies to reduce frost-induced deformation in future construction projects.

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